AIRCRAFT & MISSILES

A Chilton Publication APPLIED ENGINEERING FOR THE AEROSPACE INDUSTRIES June, 1960

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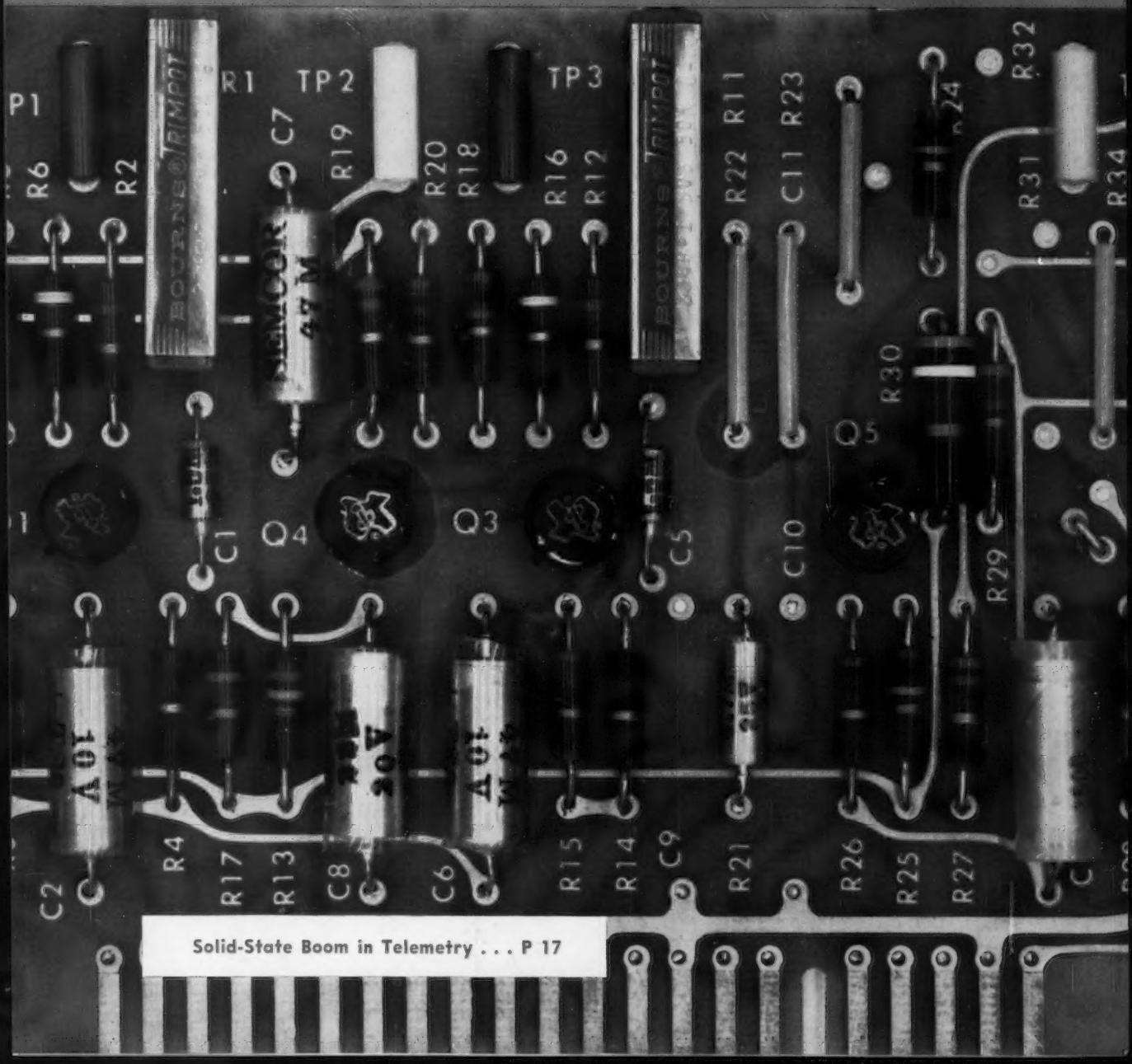
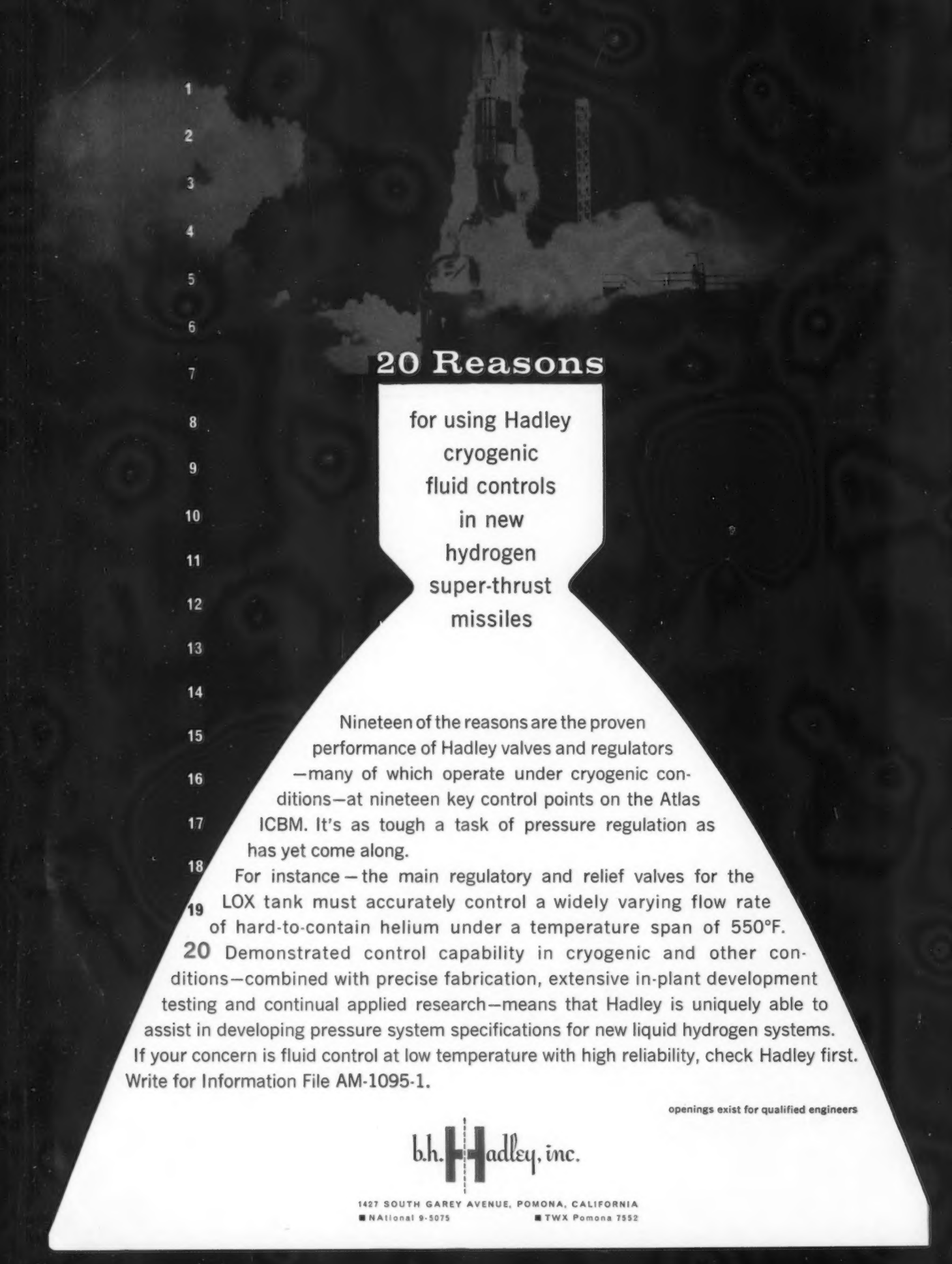


Solid-State Boom in Telemetry . . . P 17



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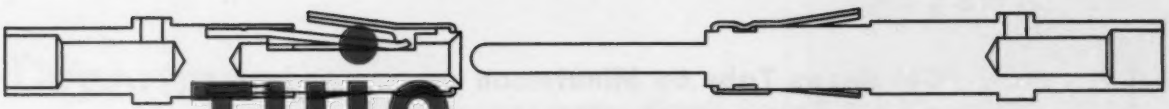

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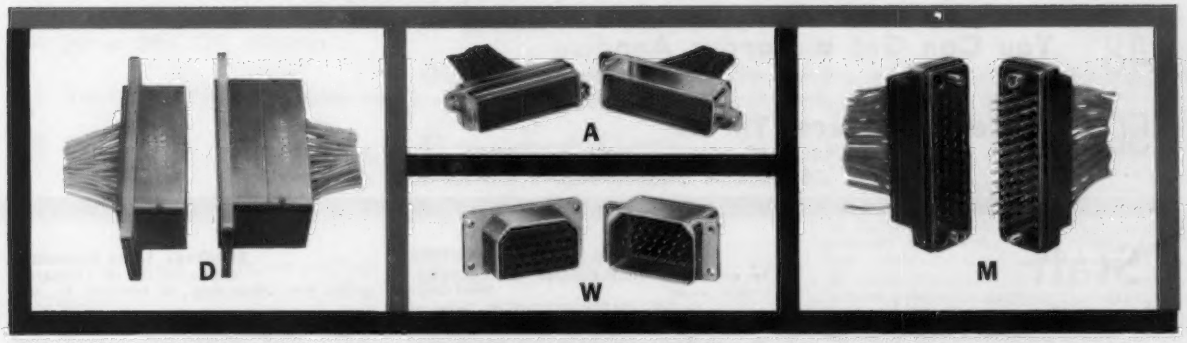

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June, 1960 *Volume 3, Number 6*

AIRCRAFT & MISSILES

APPLIED ENGINEERING FOR THE AEROSPACE INDUSTRIES

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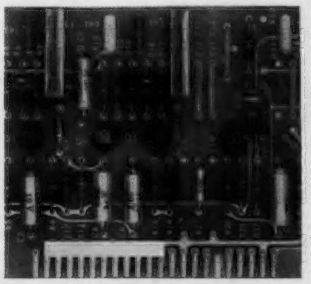
THE COVER STORY

Electronic checkups on a missile in the making—Minuteman—are used to verify design data during test firings. Airborne telemetry, and ground data-acquisition systems make liberal use of solid-state devices. These reduce size, weight, and speed tests. Tight development time in Minuteman has been compressed another year. See Page 17.



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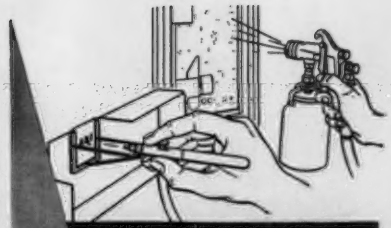

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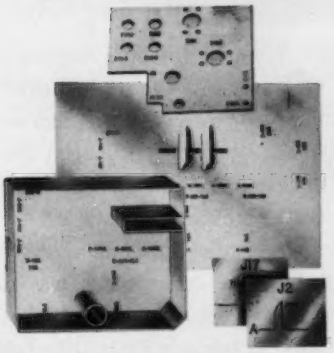

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Is The U-2 Incident Our First Brush With Space Law?

How high is up? Anyone care to comment? Quite a big hassle we had over the U-2 incident. Factions, U. S. that is, seem well divided on the subject. Comments ranged from, "so what," to "international air law must be observed at all costs."

Regardless of opinion, everyone should stand behind the order which was carried out in the best interests of the country. Our hat is off to Lyndon Johnson for rallying both political parties around-the-flag.

Conventional on-the-ground spying is a rather accepted practice. Once, however, it's done by crossing borders by air, it takes on much greater international significance.

This leaves us in great wonderment about the opening sentence. How high is up? How much air space does any nation control by law?

Surely, if we take the old three to ten mile territorial water boundary, then the U-2 was well within its rights. But, if all space above national boundaries is within the territorial limits of each nation, then, very definitely, the U-2 shouldn't have pulled the "Steve Canyon," by law.

After all, the U. S. and probably Russia have satellites either available or on-the-board that contain equipment for electronic or photographic reconnaissance far superior to the U-2. Does this mean that countries can start shooting down any satellite crossing space borders? No one, we feel certain, wants this to happen.

Let's get a legal definition of "how high is up?" Some long overdue action on space law may be staring us in the eye.

No question at all that open skies are the best answer, unless you have something to hide. Of course, the free sky idea involves complete trust in all nations. We can pray that someday this will come to pass.

Tom MacNew
Editor

SOME PARTS OF THE FUTURE CAN BE SHAPED ONLY AT THE HUFFORD SPIN FORGE FACILITY

Your source for complex and/or massive surface-of-revolution components, until now "too difficult and expensive to attempt," is the Hufford Spin Forge Facility at El Segundo, California. Here, Hufford Engineering Services, working closely with Hufford customers, is advancing hour by hour the threshold of spin forge applicability. Giant, fully automated Spin Forges are capable of shear forming a part 10 feet in diameter, 30 feet long. They can produce one part or a multitude of identical parts from high strength metals (to 1¾" wall thickness) in minutes, whereas former methods would take days. For assistance in handling your surface-of-revolution parts production problems, contact The Hufford Corporation, 1700 E. Grand Ave., El Segundo, Calif.

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Your Datebook

June 5-9
Semi-annual Meeting and Aviation Conference
The American Society of Mechanical Engineers
Statler Hilton, Dallas

June 5-10
Summer Meeting
Society of Automotive Engineers
Edgewater Beach Hotel, Chicago

June 14-16
35th Meeting
Aviation Distributors and Manufacturers Assn.
Queen Elizabeth Hotel, Montreal

June 14-17
Industrial Engineering Seminars
Cornell University
Ithaca, N. Y.

June 23-25
16th Annual Meeting
Institute of Navigation
U. S. Air Force Academy
Colorado Springs, Colo.

June 27-29
Fourth National Convention on Military Electronics
Institute of Radio Engineers
Sheraton-Park Hotel, Washington D. C.

June 28-July 1
National Summer Meeting
Institute of the Aeronautical Sciences
Ambassador Hotel, Los Angeles

July 18-19
Liquid Rockets and Propellants Conf.
American Rocket Society
Ohio State University

August 8-11
Western National Meeting
American Astronautical Society
Olympic Hotel, Seattle

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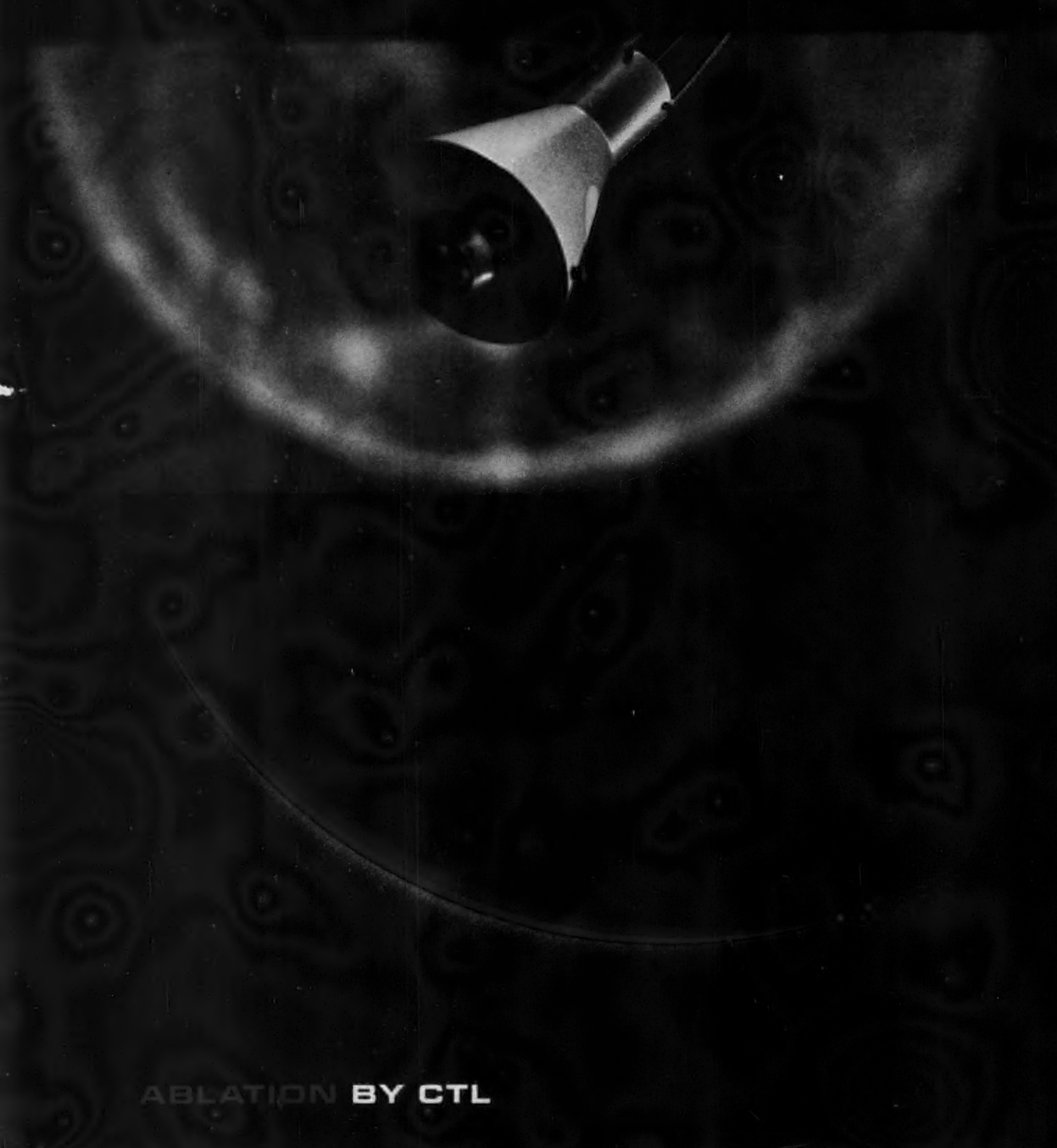
Circle 10 on Inquiry Card →



ABLATION BY CTL

Heat dissipation by the gradual and controlled separation of matter—an area of intense research at CTL for several years. If heat flux on any surface in your design ranges from 50 btu/ft² sec to 50,000 btu/ft² sec, benefit from CTL's work with reinforced plastic fabrications. Development of high temperature resins plus sophisticated reinforcement fiber orientation has made it possible for CTL to provide effective, low-weight fabrication —expansion cones of Minuteman, the nose of the Jupiter, the face of the Mercury. Find out how CTL can assist with your heat insulation problems. Request Bulletin 160.

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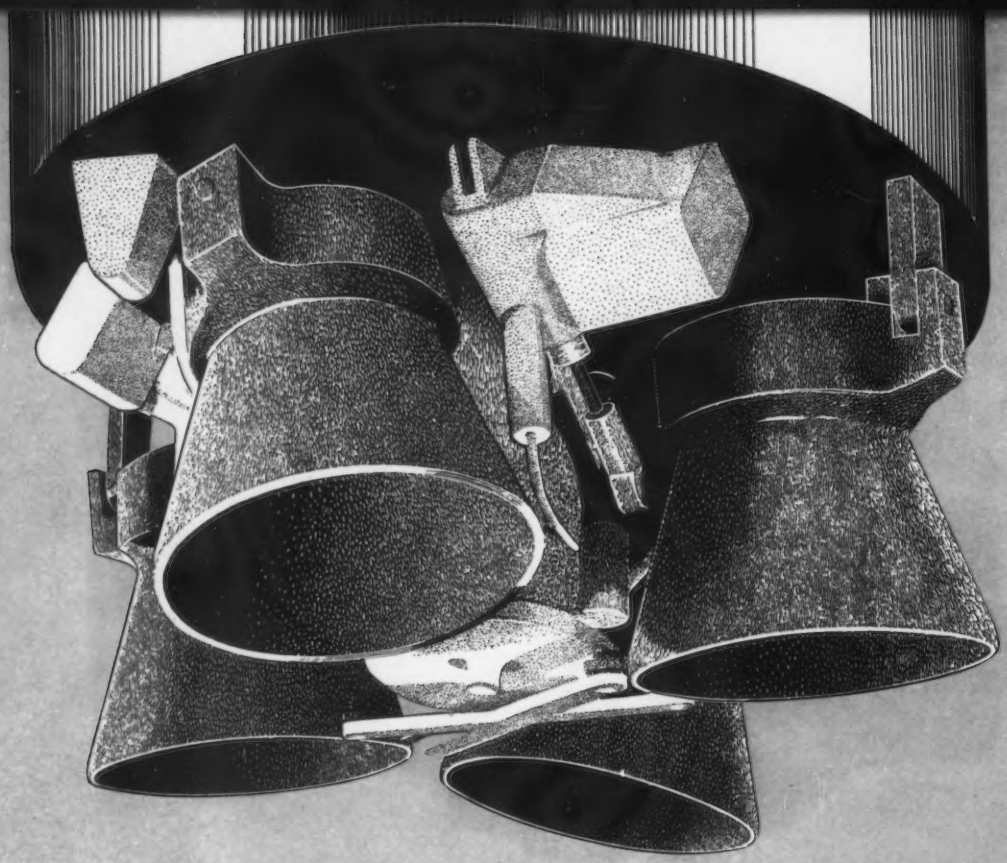
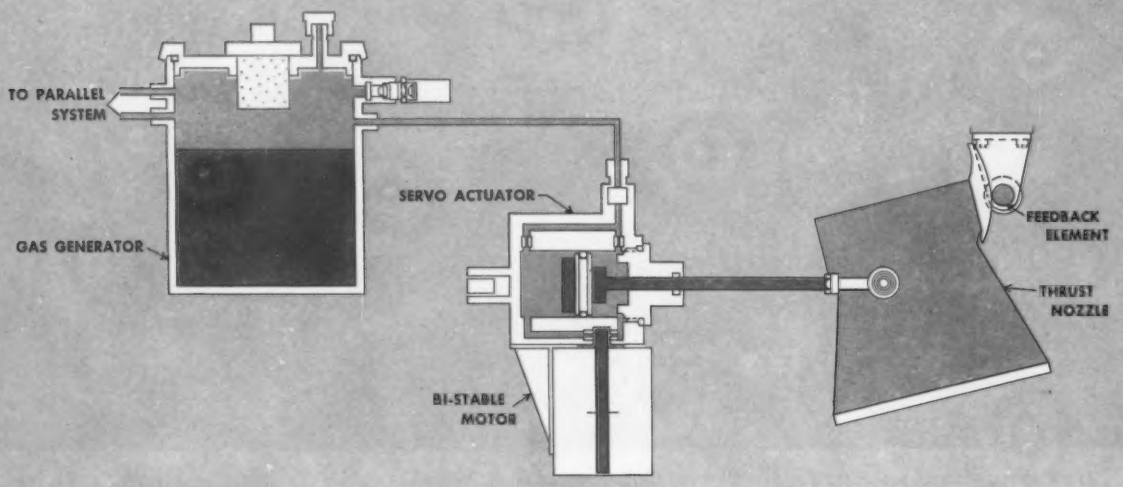


BI-STABLE SYSTEM HIGHLIGHTS
CECO HOT GAS DEVELOPMENTS



CHANDLER EVANS CORPORATION

HOT GAS ACTUATION SYSTEM IN CECO'S BI-STABLE MODE IS

- **more accurate**
- **insensitive to solid fuel contaminants**

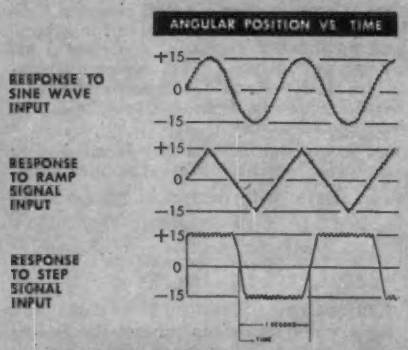
To position a mechanical load in response to an electrical command with minimum error, CECO has developed solid-fueled hot gas actuator systems operating in a bi-stable mode.

In a closed-loop arrangement, increasing the system gain to the point of *infinite* gain produces bi-stability, i.e., the servo valve can assume only two positions: fully closed in either direction. Maximum corrective torque is thereby applied to the load for all errors. With infinite gain, the system will sustain steady-state, limit-cycle oscillation, and the average steady-state error is zero. This is significant in systems with large stiction loads, since proportional controls of conventional philosophy permit larger errors before stiction torque is overcome.

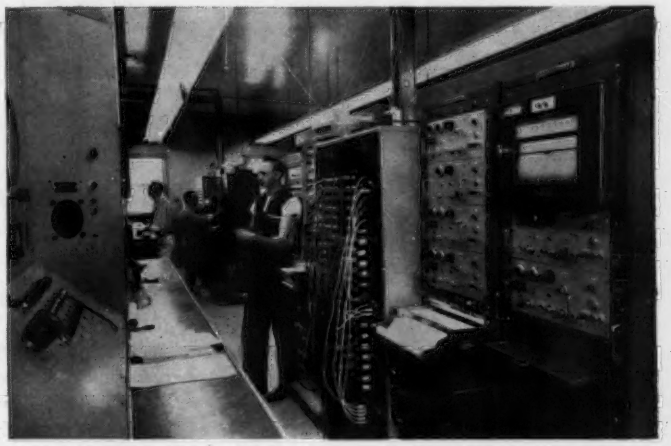
Among applications for CECO's limit-cycle, bi-stable philosophy is *thrust-vector* control. A representative portion of such a system is shown schematically at the left. This design utilizes push-pull actuators. The bi-stable motor, valving and actuators are an integral unit. One large servo-actuator positions the mechanically-linked pitch nozzles, while two smaller actuators position the remaining nozzles in response to yaw and roll commands.

CECO's experimental development program has demonstrated that because of its inherent accuracy and insensitivity to contaminants, the bi-stable control is more reliable than other proportional configurations for solid fuel applications.

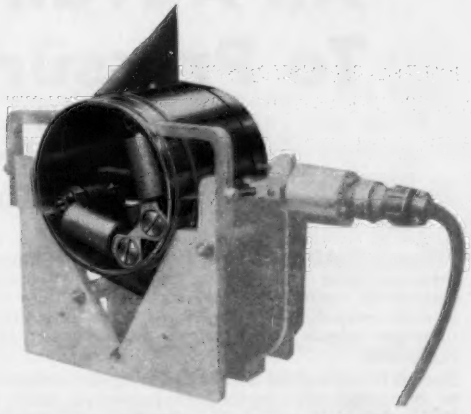
TYPICAL PERFORMANCE OF A BI-STABLE CONTROL



Response of this system to sine, ramp and step inputs (while using a conventional torquemotor) is illustrated. With new components being readied, limit-cycle amplitudes of one-tenth of one degree are expected.



Much of CECO's hot gas system and component development work is carried out in a special facility comprised of the above control room and its associated test cells.



Shown mounted in a test rig, this CECO hot gas system was designed for control-surface actuation.

Familiarity with systems engineering and with precision manufacturing for aircraft and missiles has served CECO well in its extensive work with hot gas servo control systems.

Both actuation and reaction systems have been designed, developed and produced for use with high-pressure hot gas generated from either solid or liquid propellants.

An up-to-the-minute, color-slide presentation containing technical data and a review of hot gas component and system hardware development activity at Chandler Evans is currently available. To arrange to have this presentation given before an engineering group in your company, call or write your nearest CECO Field Engineering Office.

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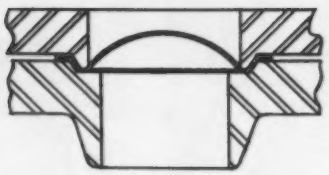
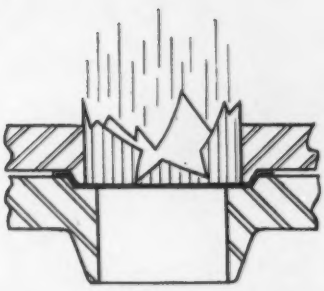


As long as pressure remains below the pre-determined point at which the dome-shaped disc will rupture, a leak tight seal is maintained.



When pressure attains the rated rupture point of the disc, instant release is provided through full orifice diameter by the outward bursting of the rupture disc.

An Advanced Approach To Pressure Systems Design

How To Reduce Weight Factor In Pressure Release Mechanisms

Although BS&B Safety Heads, in one form or another, have been providing over-pressure protection for closed pressure systems in numerous industries for more than 25 years, it is only recently that they have come into their own as pressure release devices for various types of airborne equipment.

Recent metallurgical and engineering developments, as well as improved manufacturing procedures, have made the BS&B Safety Head today's lightest weight, most accurately calibrated pressure release device ever developed. A typical Safety Head consists of a metal rupture membrane secured in mounting flanges. There are no moving parts.

Weakness A Virtue

The rupture membrane, or disc, is a purposely designed "weak spot" in the pressure system. Over-pressure bursts it at a pre-determined set pressure rating.

Full relief area is achieved instantly. When the disc ruptures a full throated opening is provided. This outstanding feature is most advantageous in pressured systems where ignition or exothermic reaction during a process causes abnormal pressure rise in seconds or milliseconds.

... This briefly, is the function of a BS&B Safety Head as related to over-pressure protection.

Imagination The Only Limiting Factor

The application and design of Safety Heads is continually being expanded. BS&B Safety Heads are serving the aircraft and missiles industries in ground, air and marine applications.

As an example... visualize the rupture disc as a seal to retain pressure in a chamber, and actuated (burst) by pressure developed within seconds or milliseconds. The pressurized fluid is thus discharged into another chamber. Here ignition may take place with contact of another fuel component. Chemical reaction may instead serve to further energize the system.

As a different application of the same basic device, the rupture disc of a Safety Head could serve as a signaling device... or to retain pressure to a pre-determined point whereupon it would then be actuated by an explosive squib or primacord.

Peculiarly Suited To Airborne Mechanisms

Weight is of prime concern in airborne equipment. The smallest Safety Head now in production weighs only a fraction of an ounce. It is about the size of a large pea. In spite of its minuscule specifications it still retains all of the design features and precise operating characteristics so essential to satisfactory performance.

Big Or Little, High Pressure Or Low

BS&B Safety Head sizes range from ⅛" to 44" in exposed diameter of the rupture disc. Pressure rating for the disc can be anywhere from 5 psi. to 100,000 psi. Mounting flanges and rupture disc metals can be varied over a wide selection to accommodate exposure to acids or other corrosive conditions as well as to elevated and sub-zero temperatures.

Hundreds Of Design Variations Possible

If you need pressure release devices of small size and light weight for missiles and JATOS, or large sizes for ground fueling systems and engine test facilities, you should examine the advantages of using BS&B Safety Heads. Chances are there is a Safety Head of the necessary characteristics available from present designs. If not, it can be custom built to your specifications.

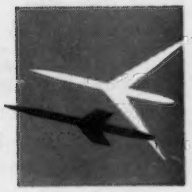
Here then are just a few of the reasons why BS&B Safety Heads can serve you better in many different applications...

- A pressure relief device with controlled release accuracy.
- Leak tight.
- Light weight.
- No movable parts.

For answers to your specific questions contact the Safety Head Division at the General Offices in Kansas City, or the BS&B Field Sales Office or Sales Agent located nearest you.

BLACK, SIVALLS & BRYSON, INC., Safety Head Division, Dept. 2-GC6, 7500 E. 12th Street, Kansas City 26, Missouri

Data Capsule



SUMMARY OF MANAGEMENT TRENDS AND TECHNICAL DEVELOPMENTS IN THE AEROSPACE INDUSTRIES

MISSILES AND SPACE VEHICLES

Design

MANNED SPACE STATION know-how has advanced to where scientists say a station can be orbited in three to four years. Types which could be assembled in orbit are believed about a decade away.

INFLATABLE FABRIC STRUCTURES are being proposed by Goodyear Aircraft for multi-manned stations. Nose cone makers are designing rigid stations based on extension of nose cone technology.

MERCURY HEAT SHIELD redesign called for removing honeycomb from ablative device and "beefing-up" with solid reinforced plastic. Machining honeycomb out of existing shields was said to be easy.

COURIER SATELLITE will have 10,000 solar cells around the four foot diameter sphere.

TITAN SILOS use 42-in. thick reinforced concrete doors. Silo doors have been tested at special sites. Reinforcing steel in underground complex is as heavy as #18 bar—two-inches diam.

HEAT DISSIPATION from power generators in underground complex of hard Titan sites was major problem. Powerhouse is equipped with four, 1000 KWA units.

Development

SPACEFORCE PLANS have been revealed by Strategic Air Command (SAC). Timetable sees manned orbital vehicle in 1963, ballistic missile with terminal guidance by 1964, space station by 1970, moon base by 1975, and interplanetary scouting beyond 1975.

IN-SILO LAUNCH capability is planned for Titan beginning with seventh squadron. Earlier missiles will be raised to ground-level by elevator before firing.

SUNFLOWER I, three kilowatt solar power unit, is being developed for NASA by Thompson Ramo-Wooldridge. One-third scale model will be used as precision template in developing two full-scale prototypes. System will require sun-seeking orientation system and an attitude control system to keep it pointed towards the sun within plus or minus one degree.

CONTROLLED THRUST variation of a solid propellant rocket motor is now possible. Rocketdyne varied thrust 70 per cent through a new controllable nozzle. Development will give missiles greater accuracy and control.

BLUE STREAK CANCELLATION in Britain wrote finis to a $270-million development program. Project, cancelled in favor of Skybolt purchases, may yet continue at a slow pace as a satellite launcher.

MINUTEMAN test launches from silos at Edwards AFB have been completed. Missile was tethered by 2000 ft of nylon cable. In eight silo tests, data was obtained on acoustics, heating, pressure and vibration of the first stage.

DYNA-SOAR PROGRAM got an anticipated boost when the Air Force made $29.7 million available to Boeing for design and ground test of the boost-glide vehicle. Martin Co. confirmed that the two-stage modified Titan launching vehicle will be built at its Baltimore facility.

LIQUID FLUORINE research at Bell's Niagara Div. is concentrating on assembly and test of working engines.

The fluorine acts as oxidizer, while liquid hydrogen would be fuel.

ELECTRIC ROCKET ENGINE preliminary development studies will be conducted by Avco and GE. "Breadboard" plasmajets will be built during the next year.

SUBROC PROPULSION is meeting obstacles. New areas involved include a fusing system which is different from Polaris, and its unique path—from submarine, through the air, then back through water to target.

PROJECT SUNRISE, new ARPA program, aims at filling gaps left by government and private research, and making "contributions of a conceptual nature to basic technical problems vital to national defense which may not be receiving adequate attention."

Production

PYROLYTIC GRAPHITE will reportedly be used for nozzle inserts on major space rockets. Ten times as strong as ordinary graphite, it figures strongly in plans for nose cones, space vehicle air-frames, nuclear fuel-element covers. GE's Metallurgical Products Dept. has produced 12 x 15 in. plates and is working on larger pieces.

Procurement

FIVE ADDITIONAL ablative heat-shields for Mercury capsule have been ordered.

AGENA B launch vehicles—16 of them—for satellite and space missions have been purchased by NASA. Lockheed will deliver them over the next three years.

AIRCRAFT

Design

BOMB EJECTOR on TAC's F-105 rams weapon out of bomb bay with 19,000 lb force. Can also be extended and retracted slowly to act as hoist in loading bomb.

FAN-IN-WING VTOL, which has reportedly reached 150 ft at Curtiss-Wright's Aeronautical Div., Woodridge, N. J., has turbines mounted near wing tips.

NEW AIRCARS at Curtiss-Wright will have turbine engines. Cars are expected to exceed 87 mph which was speed reached by second model already delivered to the Army.

YHC-1B CHINOOK will have engines in pods on side of fuselage. Gas tanks will run outside most of cabin area. To replace H37 medium transport, Chinook range is 1000 nautical miles. It can land on water, unload, take-off.

CRUSADER F8U-2N has new Y-shaped pylon making possible double Sidewinder armament than on present aircraft.

Development

BLOWING BOUNDARY-LAYER-CONTROL is under test at Lockheed-Georgia. C-130B testbed uses two T56 load compressor jet engines outboard of wings. Engines send high velocity air through a ducted system over flaps and all control surfaces. Tests include flying at indicated air speed of 50 knots, takeoff and land in about 500 ft.

MACH 2 TRANSPORT is planned by French firms of Dassault and Sud Aviation. It will be short range type with maximum of 2000 miles.

NUCLEAR POWERED AIRCRAFT research is reported to have taken "significant strides" in development of indirect-cycle system at Pratt & Whitney. Present plans call for fabrication of an experimental ground-test reactor to prove out the basic materials and components.

B-70 stripped down version slated to fly August '63.

HUSTLER will undergo flight tests as supersonic transport at Edwards AFB. Project sponsored by NASA.

Production

DOUGLAS WILL BUILD five engine pods and stubs for first GE aft-fan engines to power Caravelle. The $2.1 million contract calls for delivery in November.

Procurement

VERTOL GETS ORDER for five additional Chinook copters from AMC. Contract now totals $36 million covering 10 Chinooks and related equipment.

ARMY BUYS CANADIAN transports, 22 of them, from DeHavilland Aircraft. Delivery scheduled for January '61. Engines, props, and other accessories for Caribou planes will be procured from various makers under separate contract.

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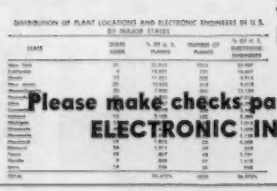

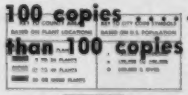

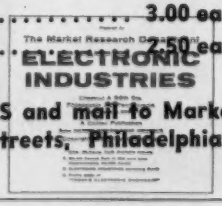

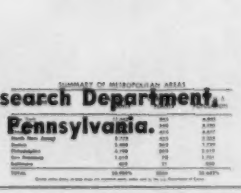

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Reader's Orbit

How Pure is a GEM?

In the article "Design Considerations for GEM's" by E. K. Liberatore (A&M April issue), the author states that the GEM of the future will be able to cross the Atlantic Ocean in less than a day. This implies a speed of 3000/24 = 125 mph or more. The product of the aerodynamic and the propulsive efficiencies of a GEM (or any aircraft in an unaccelerated flight) is:

$$\left(\frac{L}{D}\,\eta_p\right) = \frac{WV}{375\ BHP}\text{, where}$$

L/D = lift to drag ratio
η_p = efficiency of fans and ducting
W = gross weight (7000 tons)
V = 125 mph (assumed)
BHP = 400,000

Therefore (L/D) η_p in this case is equal to 11.67, which is of the order of an aerodynamically clean fixed-wing aircraft. The (L/D) η_p of the most efficient present machine designed by Weiland (flying at approximately the same h/D = 0.02) is less than 3. Considering this, and even allowing a generous improvement of the art in the future, the speed of 125 mph implied in the article appears to be unduly optimistic. Our investigations indicate that for the future GEM of this size and power-loading it would take more than two days to cross the ocean.

A. N. Petroff
Director of Research
Cessna Aircraft Co.

Mr. Petroff has a valid reason in questioning the future GEM L/D. In fact this very point was the subject of a heated discussion at the Princeton GEM Symposium last Fall. Numbers were given in the article merely to provide a rough idea of the size of a future GEM. Mr. Petroff's argument is based on the premise that the future GEM is unlikely to reach an (L/D) η_p of about 12, since this represents the value for fixed-wing aircraft. In terms of present GEM's he is correct. However, it should be recalled that airplane drag is the sum of profile, induced and parasite drag. GEM drag is the sum of parasite and momentum drag. To get an overall equivalent L/D, the GEM cushion power is converted to drag at the given speed. Therefore, to say the L/D of a GEM cannot reach 12 or so means essentially the GEM momentum and cushion drag cannot exceed the induced drag of a wing (this is for a given weight, parasite/profile drag and propulsive efficiency). Calculation of momentum drag, based on current knowledge, will show relatively large losses. But, it is Mr. Liberatore's opinion that a substantial amount of this loss can be recovered, and the total momentum flow can possibly be reduced by better cushion-sealing methods. Better sealing will also result in lower cushion power. Mr. Liberatore further states that "We are not presently trying to see how 'pure' a GEM we can build; we are rather interested in satisfying a need in transportation."

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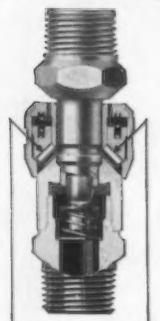

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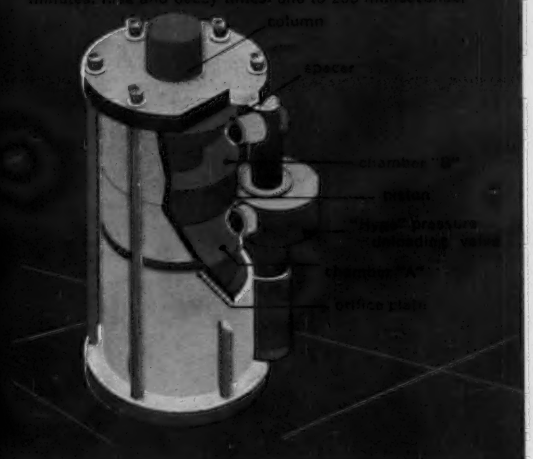
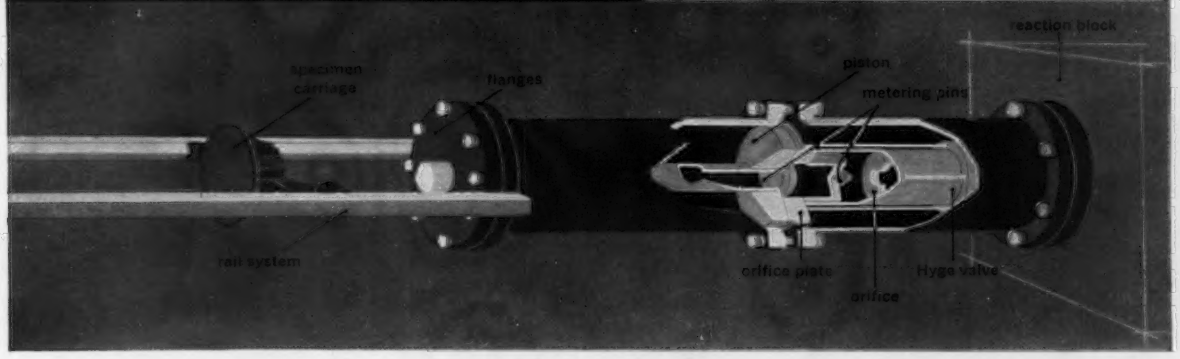


MODEL/347 • SHOCK-TEST FACILITY
This machine provides great versatility and control of g level, duration, wave form, and specimen mass. It can produce, for example, a 3000 g short time peak, followed by a ¼ cosine impulse. Typical application, simulation of 2-phase water re-entry shock. Rated maximum thrust, 450,000 lbs. External deceleration by a 60 ft. rail system. Specimen mounted on carriage with friction brakes.



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How PCM Keeps Tabs On Minuteman

Rapid, accurate data acquisition in test firings is used to verify theoretical performance; Pulse Code Modulated (PCM) techniques, solid-state devices dominant in airborne and ground-bound systems

By John P. Kushnerick

Time has been compressed in the development cycle of Minuteman ICBM. The missile will reach operational status by the summer of 1962, one year ahead of schedule.

Eight in-silo launches using a fuel-size missile and an operational type silo have been made. All were successful, and this phase of the testing program is now history. At Thiokol - Utah, flight - weight first stage engines have already been static fired. Aerojet-General Corp. recently announced it has done similar tests with the second-stage engine on the West Coast. These data, and a mass of other information will be assimilated, flight hardware will be mated, and the actual missile will begin flying in August.

Role of Telemetry—How can so much data be collected, evaluated, and put to use so rapidly as to chop one year off an already short development cycle? The answer is, of course, good initial design and engineering. But, electronic data collection devices and telemetry equipment have played a giant role in gathering data to verify the basic design.

The average missile test lasts only a few minutes. Entire systems must be evaluated in this time. The rate of data collection is phenomenal. A recent survey of the aerospace industries reveals that on large "birds," the average desired rate of data sampling is 75,000 bits/sec. Over 10 per cent of all users would like to collect much more information—1 million bits/sec. They want, need, and in some cases get, accuracies as fine as ± 0.1 per cent. These findings are the result of a study conducted by Aeronutronic, a division of Ford Motor Co. It was sponsored by the three services under contract DA-36-039 SC-73182. Aim was to give telemetry designers some direction in military's requirements for data collection equipment in the next decade.

PCM and the Minuteman—The data collection devices that will continue to speed Minuteman development are at the forefront of the state-of-the-art in telemetry.

FM-FM systems which have been "standard" from the beginnings of radio telemetry have been largely by-passed. PCM (Pulse Code Modulated) digital telemetry will be dominant in Minuteman's flight test program. PCM has several basic advantages:

- Greater number of performance variables can be monitored at fast speeds (24 kc word rate) by sequencial sampling, multiplexing and transmission of digital signals.
- Analog information is converted immediately to digital binary code, preserving high accuracy during transmission and processing.
- Digital data can be quickly prepared in proper computer entry format.
- Relatively noise-free signals can be provided due to simple on-off characteristics. These can easily be recorded on magnetic tape.

The digital PCM system that will fly with Minuteman is built by Radiation Inc. It features a low-level multiplexer which allows mixed data sampling from strain gages, thermocouples, and various other sensing devices on any one of several hundred channels. Some channels can be sampled at high rates, others at lesser rates depending on the accuracy required.

Solid State Devices—The solid-state, low-level multiplex circuit has a 10 microvolt resolution; previous low-level systems had a ten millivolt limit. This means an improvement in error detection of 1000 times.

Elimination of preamps, with attendant size and power requirements, allows Minuteman's telemetry to be small and light. Over 300 data channels will be handled in a unit occupying less than one cubic foot, and weighing less than 50 lb.

Sensing and transmitting the electrical impulses that represent component and system performance is only half the job. They must be captured as fast as they are transmitted. Typical of the devices that record and reproduce telemetry

Unique propellant evaluation scheme assures desired burning rates are built into 1st stage

signals is a solid-state analog tape recorder designed and built by Ampex Corp.

Ironically, this recorder/reproducer was not originally intended for Minuteman. But, it fit Boeing's needs well. So, Ampex invested $2 million of its own money and compressed normal product development time from 2½ years to 18 months to meet Minuteman's accelerated schedule. One unit has already been shipped to Boeing Seattle; 16 others will follow through 1960. They will be used at Edwards AFB and Cape Canaveral as well.

Info On 7 Tracks—The first nine recorders will have a frequency range of 300 cycles to 250 kilocycles per sec with a 60-in./sec tape speed. This is more than double the bandwidth previously available. Circuitry and magnetic head improvements are presently being engineered to extend the bandwidth capabilities of the remaining devices up to 500 kilocycles at a tape speed of 120 in./sec.

Although the recorder can handle up to fourteen tracks of information on 1-in. wide tape, Boeing selected a 7-track configuration for the Minuteman testing. This uses ½-in. wide tape made of Mylar. Standard reels with 14-in. diam, provide 24 min of recording time. Since data retrieval may take longer, the machine has a means of sensing the end of the tape and automatically switching to a second transport.

350,000 Bits/Sec—In Minuteman tests, the tape will serially record information at 350,000 bits/sec. The tape recorded data will be the primary information source to a tape format converter in the overall telemetry system.

The output of Frequency-Modulated receivers, containing serial coded PCM information, will be redundantly recorded for reliability, on three separate tracks.

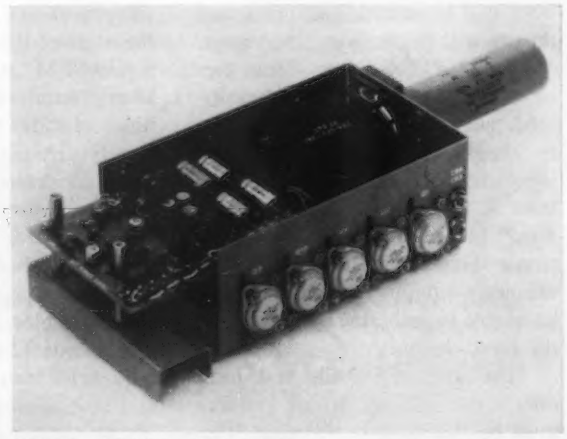
The remaining four tracks will be used for recording conventional FM/FM telemetry signals. Thus, the magnetic tape recorder has three tracks on one head-stack recording the high-density PCM information, and four other tracks on another head-stack recording the FM/FM telemetry and other information.

Solid-State Design — An all solid-state modular electronic system was adopted as one of the features to assure the design goal of 750 hr of trouble-free recording. Modular packaging permits quick replacement of individual electronic units, and the solid-state devices do not require the usual 30-min warm-up time associated with vacuum tubes. All electronic units are mounted on slide-out trays and all components are accessible from the front of the recorder so they can be adjusted or replaced within a matter of seconds.

Design Performance In — At Thiokol-Utah, first stage rocket motors for Minuteman are being cast, cured, and test fired. On this 11,000-acre site, that sees new facilities popping-up like mushrooms, Thiokol has installed devices to acquire complete evaluation data on the performance of the engines.

There is no practical way to control the burning characteristics of a solid propellant engine once it is fired. The desired performance must, therefore, be precisely built-in during manufacture. This requires accurate and detailed quality-control firing tests. Thrust and pressure must be measured at high sampling rates, to accuracies better than ±0.1 per cent. Temperature and

TELEMETERED DATA in Minuteman tests is recorded at 350,000 bits/sec on analog tape recorder. Electronic devices like this will play key role in bringing missile to operational status by summer of 1962.



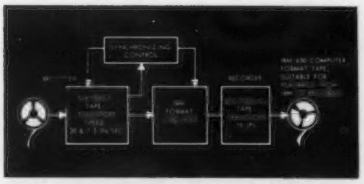
SOLID STATE DEVICES have growing importance in airborne and ground-bound data acquisition systems. Shown is the power supply for Ampex FR-600 recorder that Boeing will use in Minuteman.

operational measurements must be made at accuracies of ±0.2 per cent. Vibration and transient measurements must be made at high band width, although lower accuracies are allowed. A range timing system with high resolution must be used to correlate the variety of data obtained.

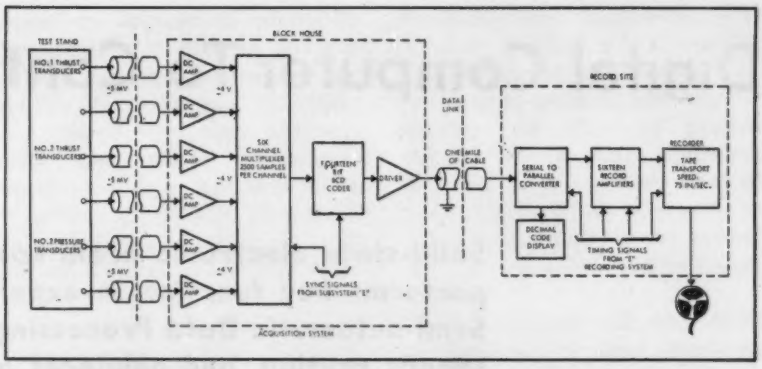
The system which does this, again, uses PCM techniques. It is believed the most accurate and comprehensive propellant testing facility in existence. Radiation Inc. is the designer and builder.

Design Summary—Six subsystems make up the overall system:

- Subsystem A is used for thrust and pressure measurements to compute the total impulse integral. It consists of two identical data acquisition and recording systems, each capable of handling six channels of data. The twelve channels can be sampled 2500 times/sec. Accuracy of ±0.05 per cent is possible with multiple samples. The acquisition systems are in a block house 300 ft from the static firing stands, and the recording systems are located one mile from the block house.
- Subsystem B is used to measure temperature and low bandwidth parameters. It is similar to subsystem A except that 24 channels are handled, each sampled 625 times/sec. Accuracy is ±0.1 per cent. Each sample is converted to a 14-bit binary coded decimal (BCD) word. BCD is used since the data is later fed into an IBM 650 computer which operates best on this mode.



TAPE FORMAT CONVERTER of unit at Thiokol uses "data editing" of tape. "Non-essential" data is screened out so it does not have to pass through computers and take up valuable time.



PCM TECHNIQUES dominate in Minuteman's many data acquisition systems. Shown is one of six subsystems in the most comprehensive propellant testing facilities known. It is used at Thiokol-Utah. This Subsystem A, is used for thrust and pressure measurements. It samples 6 data channels, 2500 times/sec.

- Subsystem C is used for analysis of high frequency vibration and transient data. It provides 10 kc bandwidth for six channels. Recording is in conventional FM fashion, at tape speed of 60 ips. It also has a high-speed search feature; when data to be analyzed is found, the recorder is slowed to 7½ ips and the information transferred to a tape on subsystem B's recording system.
- Subsystem D is a tape converter format converter. It translates data from subsystem A and B tapes into a form suitable for direct playback into the IBM 650 computer.
- Subsystem E is a range time generator which supplies timing pulses to the entire PCM system and to cameras used in photographing the engine.

Data Editing—One of the most amazing design features of the tape format subsystem is that it sorts out normal data and "discards" it so that the 650 computer is not overworked data that needs no analysis. This is a tremendous time saving since there are often up to 100 firing runs per day fed into the computer. The runs are normally short, and since there is a slowdown of real time information by 10 to 1 on the computer tape, even the most efficient "time editing" previously employed would result in exclusive use of computer time.

The data editing system works like this. Immediately before each test all transducers are calibrated. This is done automatically by pushing the "PREFIRE" button. All subsystems are calibrated simultaneously. One second after calibration the solid propellant is ignited. Just before the firing signal, a pulse is recorded on all subsystems noting that the deflection on every transducer is static. In subsystem D the static signal is used to initiate the storage of a data sample from one typical channel. When the firing has started, subsequent samples of this channel are compared with the stored static value. When the information on the channel has returned to approximately 1.0 per cent of the static value, the computer tape is stopped. Thus, only essential data is fed to the computer.

Quick-Look—Another interesting feature of the read out equipment is a multistylus type Quick-Look recorder for producing rapid and accurate digital plots of the data collected on subsystems A and B. It is commercially known as a Radicorder.

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Digital Computer To Control Air Traffic

Solid-state electronic brain sponsored by FAA performs key function in experimental center; Semi-automatic Data Processing Central speeds routing, and enhances air safety

A unique computer has begun test operations at the Federal Aviation Agency's experimental center in Atlantic City, N. J.; it will become the heart of the nation's development system for breaking jet-age traffic jams and increasing air safety.

Designed and made by Librascope Div., General Precision, Inc., the computer is the first ever designed specifically for air traffic control. It is the key element of a new data processing system that will greatly improve coordination from takeoff to touchdown of civil and military flights within a single FAA control complex.

These computer units, known collectively as the Data Processor, will make a major contribution to safer air travel—they will extend the capabilities of FAA control facilities to accommodate more aircraft without present delays. Most accidents or near misses between aircraft are caused outside the control system.

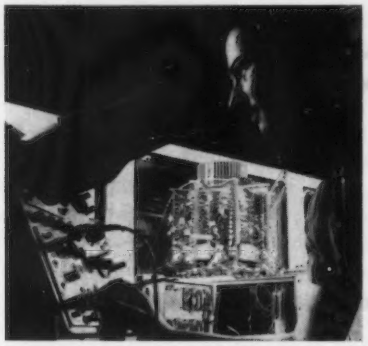
Data Processor alone consists of four major units: digital computer, file drum, buffer, and programmer's console. Each unit is 6 ft high, 3 ft deep. Number of units to be installed at a particular location will vary according to traffic requirements. By installing additional units, capacity of a facility can be easily expanded to handle increased traffic.

DATA PROCESSOR forms the hub of a semi-automatic air traffic control system sponsored by the Federal Aviation Agency. Made by Librascope Div., General Precision, Inc., this equipment will be integrated with Data Processing Central developed by GPL Div., General Precision, Inc.

Computer Capabilities — Computer combines the most modern techniques of memory drums, memory cores, and computer logic. It is expected to replace other computers now operating on a small scale in specialized air traffic control functions and become the first operational computer in the new FAA system performing system-wide operations.

As programmed for the New York area, the computer will be able to process and print up to 1600 flight progress strips per hour, process 440 flight plans per hour, and store a total of 1000 flight plans. It will also be able to sequence the arrival or monitor the departure of a total of 90 aircraft per hour.

In spite of the great volume of air traffic information that is filed, the computer can search as many as 8000 words of pertinent records in 1/30 sec. This is the result of its unique organization of file memory and control unit. There is almost simultaneous access to the computer memory from many control positions. Computer can also detect its own errors. To assure reliability of information, it has duplicate file storage as well as parity and dual adder circuits that automatically check all problem solutions to



HIGH-SPEED MEMORY DRUM in Data Processor is being checked by operator using oscilloscope. Drums rotate at 1200 rpm and contain 8-word blocks having 12-character search key and 4-character fixed address.

eliminate transfer and computation errors.

Data Processing Central and its computer have been designed in "building block" units. This makes the Central compatible with existing hardware to meet requirements of various control centers, and facilitates replacement of equipment.

Present System — Air traffic control is now performed chiefly by a nationwide network of approximately 13,000 traffic controllers who handle clearance and control of flights. Traffic controllers must maintain safe operation between aircraft flying at widely different speeds and operating at different altitudes, and carefully merge air traffic into approach and landing patterns at busy terminals throughout the country. Their work today is excessively manual — writing flight progress strips by hand and posting the strips—and communicating by voice, interphone, and radio and analyzing and computing flight progress.

New System—With the new Data Processing Central, controllers will be able to enter manually, or automatically into the new computer a variety of flight plan information such as time and place of flight departure, destination, and flight route. Computations will be completed and information presented to appropriate controllers automatically through an array of display consoles designed to be quickly and easily read. Computer will process flight plans automatically and provide navigational check points. It will alert traffic controllers as much as 30 minutes in advance whenever two aircraft are on courses that would bring them too close together for safety.

By expediting coordination between controllers among and within the nation's 33 air traffic control centers, the new system is expected to eliminate an important cause of delays in today's increasing air traffic. While the computer relieves controllers of their huge burden of manual computation and "bookkeeping," new display equipment never before available will make it easier for these men to make decisions quickly in resolving traffic problems.

It is expected that these data processing systems will be installed eventually on a nationwide basis. They are designed to be compatible with the present traffic control system so as to minimize controller retraining and allow for gradual phasing in of new equipment modules. In the unlikely event of power failure, it will be possible to revert immediately to the present fully-manual system with no danger to safety.

The computer and other initial elements of the data processing system will be operating experimentally this year at FAA's National Aviation Facilities Experimental Center in Atlantic City. Similar equipment will be installed later for operation in the New York area.

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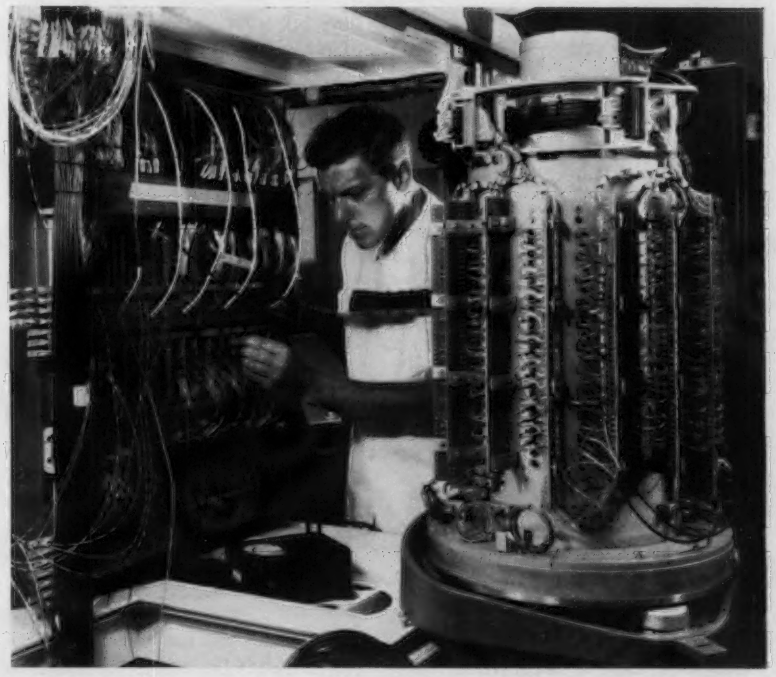


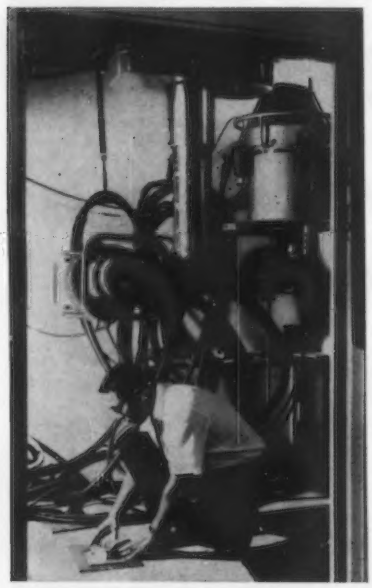
FILE DRUM is one of four major units in Data Processor. Each drum stores 16,000 words representing vital flight data.

Three-Dimensional X-Rays

Hidden defects spotted in potted or sealed components; Combination of stereoscopy and radiography adds "depth" to Atlas reliability

by J. L. Minos, Reliability Engineer,
Convair-Astronautics, Div. General Dynamics Corp.

Stereoradiography, the science of three-dimensional radiography, has been used for many years as a diagnostic tool in medicine. It has had limited use in the production of castings, steel plate, and for weld inspection.



STEREORADIOGRAPHY technique used in Convair's Atlas Reliability Diagnostic Lab is an extension of conventional radiography.

Currently, stereoradiography is adding a third dimension to Atlas's reliability; it is being used for peering into sealed or encapsulated components without destroying them. Pressure transducers, gyros, valves and regulators are effectively analyzed for defects in the Atlas Reliability Diagnostic Lab., of Convair-Astronautics.

This process is also used in destructive technique where needed. A stereo-pair of the part is taken, and after analysis an optimum entrance-path is traced. Stereo technique is especially useful where sealed components tested for failure analysis cannot be opened without invalidating manufacturer's warranty.

Encapsulating epoxies, which cannot be easily dissolved, previously presented a major problem in failure diagnosis. Tedious chisel-and-hammer chipping was used to reach the affected areas; this process often rendered the analysis of delicate parts invalid. Two-dimensional radiography proved only partially effective in such cases because spacing in depth could not be judged. The fact that encapsulated assemblies are often built up in layers aggravated this problem. Stereo was tried to radiograph parts into their true spatial relationship. The original radiographs showed this spatial arrangement but parts were distorted and focus was difficult to obtain. Accepted exposure consisted of shifting the tube right and left of center without moving the part. This took extra time in trying to accurately place the tube head at the exact point for optimum stereo effect. To correct this, tube focus was located by a spot on the floor, and one half of the normal interpupillar distance of 2.5 in. was marked off to the right and left. Presently, tube head is elevated to its uppermost travel and maintained there to allow more parallel rays to penetrate the part. At the same time the finest-grain film available is used to produce a sharp image. With this arrangement, proper spacing results in clear and easily-focused 3-D radiographs. For very small parts, the tube may be brought closer to accentuate stereo effect. After proper positioning of tube head, part is placed on the right location and exposed. The part is then placed on the left spot with another film, oriented exactly at the right exposure, and radiographed. Films are marked "R" and

"L", and with any additional information desired. Radiographs are then placed in front of illuminators, and viewed by Wheatstone system. A slight adjustment of the mirrors and radiographs may be necessary to bring them into sharp focus. Other viewers are available, utilizing mirrors and prisms to bring the stereo-pair into focus with a minimum of effort. The Wheatstone method, however, is quite satisfactory and less expensive.

Stereoradiography serves a two-fold purpose: (1) since the displacement in each film is slight, each film may be viewed singly where a viewer is not available: (2) each film may be printed in positive and viewed in stereo without using back illumination. Stereo viewers are readily available for this technique.

Stereo technique is also being used on new parts undergoing reliability evaluation. These parts are subjected to testing specifications, and after failure stereoradiographed to bring out the failure and if possible to reach defective area directly. Often, broken leads, diodes and transistors can readily be seen, and the analysis need not go any further. This results in an economy of time, as well as of testing facilities.

Stereoradiography technique may be applied to any components, provided that X-ray wavelengths produce no detrimental effects on items being tested.

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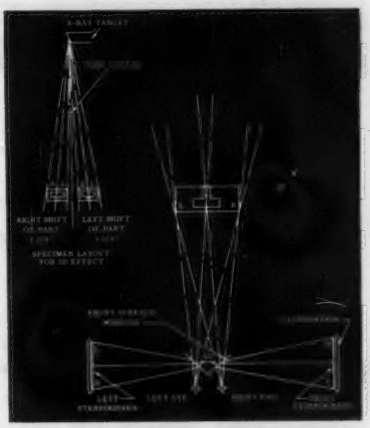
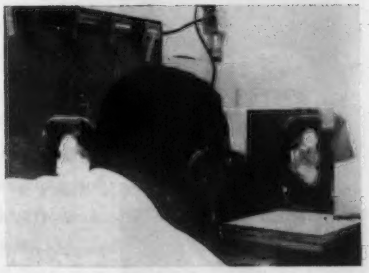
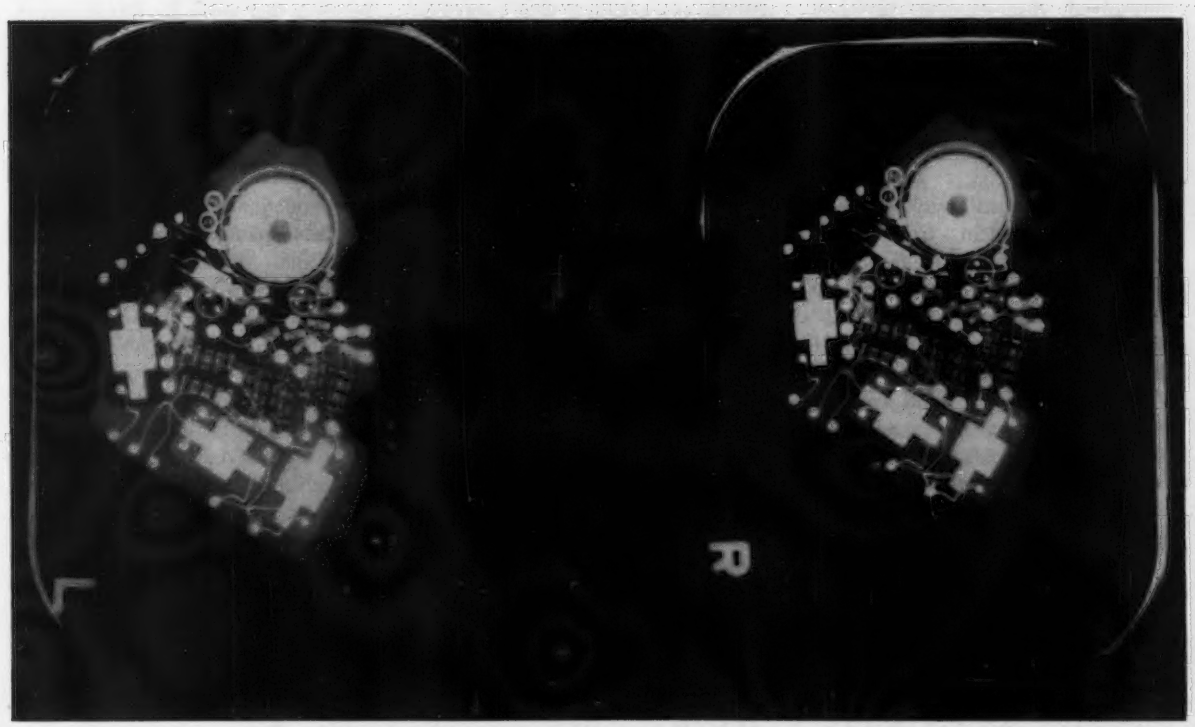




WHEATSTONE METHOD of stereo-viewing is basically simple and inexpensive; it uses a pair of mirrors forming a 45 deg angle, and two radiograph illuminator panels.



STEREO-PAIR of this typical electronic module may be viewed by a conventional stereoscope, or even by naked eye with a little practice.

Vicious Procurement Practices in DOD?

Is government red tape and invention robbing forcing small business out of the defense picture? A member of big business appraises the issues

Garrett Corp.'s Scott
"incentive for the inventive?"

Mr. Denham Scott, Assistant to Pres., Garrett Corp., was recently invited before the House Subcommittee on Small Business and Government Procurement to help set the record straight on DOD handling of the alleged Proprietary Rights of Small Business in non-patentable, technical information. As an employee of Big Business, he had no personal stake in the matter. But, his analysis of the situation was so unusual that Aircraft & Missiles offered him the editorial pages of STATE YOUR CASE as an industry sounding board for his opinions.

There is a very tragic and bitter, unresolved disagreement between the Department of Defense and its suppliers. The most persistent voices raised in protest of Procurement practices come from Small Business, but the problem is not exclusively theirs.

It is an extraordinarily deep and complicated problem. Congress is attempting to dig out the facts, fictions and misunderstandings. When they have wisely recognized and discarded the fictions and misunderstandings, they will be confronted with the contradictory and irreconcilable facts that the announced Procurement policies and the actual practices of DOD vary.

Therein lies the trouble! What caused the backfire?

Before we get to the facts we should logically ask, "Who in small business is complaining?" The answer is, "The Small Businessman who has products of his own design to offer." I think we should take a look at him. First, his name is legion. There are thousands of him throughout the US. Second, he is capable of making a vital contribution to our defense posture. Big business has no monopoly on brains. Third, he is cast in the role of a "vendor" in today's scheme of things. He is at the lower echelon of the subcontracting tier and does his business with other subcontractors or primes. He is not unhappy about this.

He wants to know what the defense industry needs, so that he can direct his ingenuity and capability to the task of coming up with a design which outperforms his competitors.

Who Pays for What?—The popular misconception that the Government pays for all of the development in Weapons Systems is a monumental piece of fiction. The typical Small Businessman must dig into his own pocket to finance the sales promotion and brainwork necessary to design and produce, test and refine the specialty item which will best solve a given problem. This he does in an atmosphere of keen competition. He therefore believes that since his blood, sweat, tears, and money were invested in creating an improved product, the Government should permit him to retain the same proprietary rights on his engineering drawings as he would have in selling such products to commercial users.

Inescapably Bound—It is at this stage that Mr. Small Businessman must face the stark realities of Defense contracting. He now learns that he must inescapably become contractually obligated to conform to a bewildering maze of regulations, specifications, contractual clauses, P.A.R.O.'s, inclusions, tables, and "whatnot's." Most of these he has no access to, and all stem from the Government with whom he has neither a contract nor a contact. By Government decree, they are fully applicable to him, regardless of which level or tier he occupies in the subcontracting structure.

He discovers that he is automatically and simultaneously con-

fronted with accepting the requirements of a Specification (MIL-D-70327) and a Regulation (A.S.P.R. IX, Part 2). The first of these tells him that he must prepare a complete set of technical data suitable for manufacture by others. The second, A.S.P.R., tells him that, if the Government examines his drawings and process specifications and decides that his design and know-how are discoverable by the process of reverse engineering, the Government will deem his drawings and processes to be non-proprietary. The Government then becomes free to use his drawings to shop around among those who have nothing to offer but machines.

He has no intention of allowing his honestly-earned know-how to be turned over on a silver platter to this type of competition, and is convinced there must be a mistake somewhere. After all, he reasons, he is a representative of Small Business, with the brains and initiative to develop a needed item. He did so at his own risk and expense. Surely, he reasons, there are laws and it is inconceivable that his own Government would confiscate his property.

Can It Be True?—He therefore looks around for the mistake. He learns first that he must indeed prepare his drawings in accordance with MIL-D-70327, because the Honorable Perkins McGuire addressed a memorandum to the Assistant Secretaries of the Army, Navy, and Air Force on the 9th of April, 1959, on the subject of MIL-D-70327 — Drawings, Engineering and Associated Lists. Pertinent excerpts from this letter follow:

> *"I have this day approved the subject military specification." . . . "This specification is mandatory for use by the military departments in connection with (1) all production contracts, and (2) Research & Development contracts resulting in a design released for production." . . . "The requirements of the specification are effective with respect to drawings prepared by the military and industry and its requirements are to be invoked by prime contractors with respect to procurement by them from subcontractors and vendors." . . .*

The Army, Navy, and Air Force, therefore, have clear instructions to invoke the requirements of MIL-D-70327 down through the layers of subcontracting. Each of these Procuring Services implement these by different methods, but each of them has adopted an inescapable system.

As an example, the Air Force currently calls out MCP 71-77 in all of its R & D and Supply contracts. This document spells out that contractor's drawings and data must be delivered to the Air Force; must conform to the requirements of MIL-D-70327; and must be in microfilm form with a supporting deck of Punch Card Accounting Machine Cards.

In searching for the mistake, or at least a possible escape, our Small Businessman finds out that he must prepare a package of data (MIL-D-70327) and that he must submit the data in microfilm form with a deck of cards (MCP 71-77). This does not bother him too much. He wants his products to enhance his reputation by rendering reliable service in field operations. He recognizes that Government personnel must catalog them, repair, overhaul, and service them. He is, therefore, quite willing to supply drawings for these purposes. But, microfilm costs money, and so does the acquisition of the deck of cards. These may or may not have been figured in his original quotation price. But at all events, he reasons, it is a service that the Government is insisting on; therefore, the Government should pay for it. He agrees to submit a set of technical data in reproducible form.

Unwittingly Trapped—The mistake he was looking for has not yet been found, but in all probability he, himself, has just made a big one. If as is likely, the prime contractor is operating under a contract in which the Unlimited Rights clause is stipulated, then our Small Businessman has just fallen into a trap. He must accept the conditions which prohibit him from labelling any part of his data as being proprietary. And, he must agree that the Government can use this data for any purpose whatsoever. The prime contractor is sympathetic but powerless to help him. The Procuring Service has merely implemented the requirements of a mandatory Regulation A.S.P.R. IX, Part 2, and it, too, is unable to provide relief.

Still pursuing the mistake and having thus unwittingly stumbled into the Unlimited Rights clause of A.S.P.R. IX, Part 2, our friend decides he had best study that document. He soon discovers that there are two versions, one dated April 9, 1957, and the other dated October 15, 1958. He, in his role of subcontractor, stubbed his toe on the earlier version, because it is very much alive today since the primes are currently placing purchase orders under contracts containing it.

Faith Restored—In his study of the two versions, he finds what he is looking for in the later version. There it is, in black and white, a beautiful statement of Department of Defense policy, most quotable (and indeed often quoted to inquiring Senators and Congressmen). It reads like the answer to his prayer, as follows:

> *"It is the policy of the Department of Defense to encourage inventiveness and to supply an incentive therefore by honoring the proprietary data resulting from private developments and hence to limit demands for data to that which is essential to Government purposes."*

His faith is restored. He knew all along that the Government was well-intentioned. Here is the proof. He interprets it as saying that the Government will respect Proprietary Data by normally not asking for it. This sounds good. But he recalls that he picked up a firm obligation to prepare a complete set of Technical Data. He re-reads the specification and finds the following:

> *"Paragraph 3.3.2. Delineate directly or by reference sufficient engineering requirements and characteristics for the item, such as material, dimensions, tolerances, form, finish, functional and interchangeability characteristics (electrical, mechanical, and other performance characteristics) neces-*

Government "outlaws" proprietary inventions by process of reverse engineering

sary to enable the Government or contractors to procure or reproduce the item or obtain an adequate interchangeable substitute. Sufficient information to permit engineering evaluation and testing, complete service, maintenance, repair, adjustment, and setting shall be included."

He then takes another look at Paragraph 6.1.

"Intended use. Subject to rights in data acquired under the contract, engineering drawings and lists provided and revised under this specification may be used by the Department of Defense activities for design, procurement, manufacture, testing, evaluation, production and receiving inspection, overhaul, general maintenance of equipment, construction, survey, and wherever engineering drawings are needed."

It would seem that the authors of this paragraph took no chances of overlooking anything.

Two other paragraphs from this specification, and remember it is the D.O.D. mandatory standard, are directly applicable to the acquisition of technical data from Small Business by Big Business. They are quite strong and specific in their wording.

Two Sets of Drawings—By this time our Small Business gadgeteer has wisely hired the services of a lawyer. Between them they arrive at the incredible but correct conclusion that the A.S.P.R. is based on the peculiar assumption that he will prepare two sets of drawings. One fulfills the requirements of MIL-D-70327, which although prescribed by the Government is not needed by the Government. The other he must submit in accordance with MCP 71-77. It need not contain proprietary data. He ruefully contemplates this additional expense.

The clue to this fantastic discovery is to be found in the following sentence extracted from Paragraph 9-202.1 of A.S.P.R. IX, Part 2.

"Generally it should not be necessary to obtain 'proprietary data' to satisfy Government purposes." The foregoing statement is suspect of being largely fictional, because for many years each of the Procuring Services have insisted on the necessity for a complete package of data for repair, overhaul, and emergency replacement purposes. To our knowledge, the Government personnel responsible for these functions has not changed their minds.

However, our friend and his lawyer seem to have found a chink in the maze of weirdly assorted contractual documents whereby they can negotiate. The Government, they reason, can be prevented from turning his complete "know-how" over to those who would have a free ride on his brains and investment.

Fictional Negotiation—But the cruelest shocks of all are still now to come to them. The right to negotiate is also largely fictional. In practice our Small Business friend is low man on the totem pole and can, therefore, only negotiate with his direct purchases, who of course is restricted by the terms of his contract. The following is an actual form letter response to a negotiation inquiry. It has been selected because of its brevity.

"Gentlemen:

This is to advise that we cannot delete the Rights in Data Unlimited clause in our referenced purchase order. This purchase order was issued under a Government Prime Contract which embodies A.S.P.R. 9-203.1 but does not include 9-203.2.

Please acknowledge receipt of this letter by signing one of the enclosed copies in the space so provided below and return to the undersigned.

Thank you.

Very truly yours,"

The Rudest Shock—Unfortunately, the rudest shock of all is still to come. By the very simple device of definition, the Government has invented for its own use an almost empty phrase which does not permit the contractor to restrict what he would ordinarily withhold as proprietary under common law. The A.S.P.R. definition gives no recognition to the fact that novel features of design could be proprietary and, therefore, should be protectable. It is based on the concept that, if in the Government's opinion, his "know-how" could be rediscovered by reverse engineering, then there is no need for the Government or anybody else to go through the motions. Drawings are, therefore, deemed to be non-proprietary and hence can be handed on a silver platter to those seeking a free ride on our Small Businessman's brains, initiative, and investment.

The Department of Defense, therefore, is using a unique definition and practice which disposes of the problem of proprietary rights by disclaiming that they exist.

In addition, The General Accounting Office is diligently policing the various Procuring Services to enforce the theory that the Government paid for the rights to use for competitive reprocurement purposes, the millions of drawings, microfilm, etc., which industry, large and small, submitted for the pittance cost of the paper and service. There is today a very tragic and bitter unresolved disagreement between the Department of Defense and its suppliers.

Wherein lies the incentive for any Small Business organization to be inventive in the interests of the Department of Defense?

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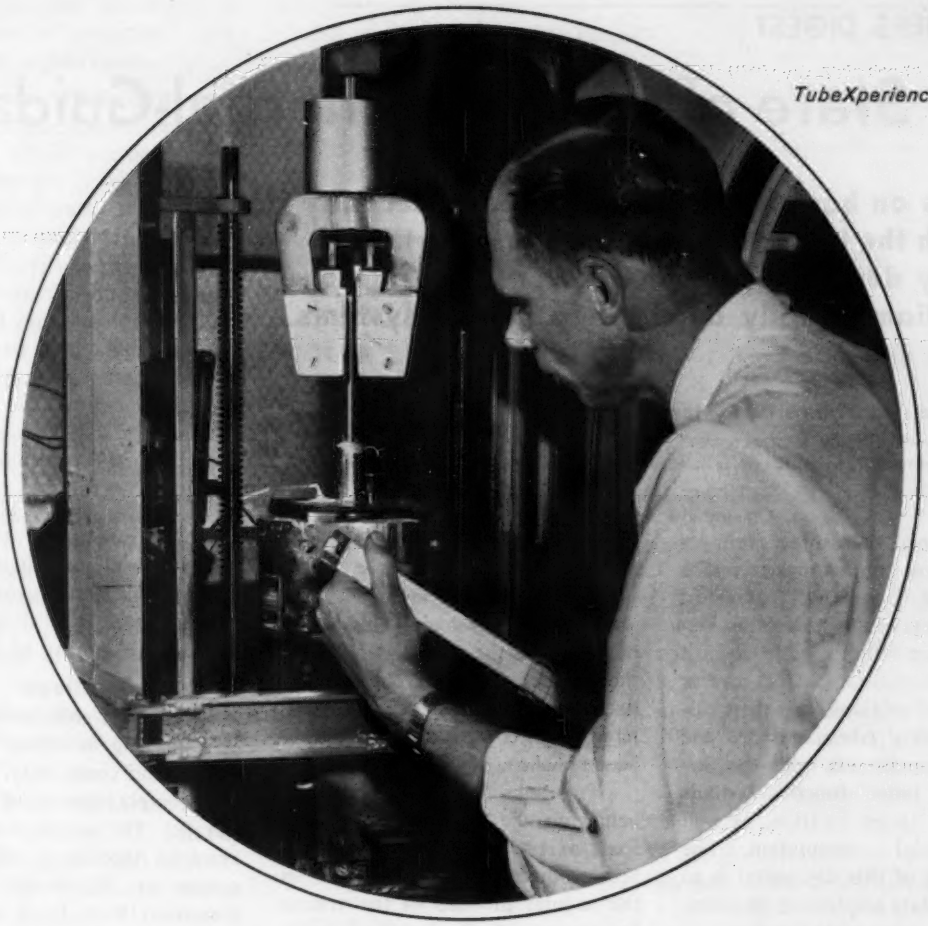

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[3]Registered trademark of Haynes Stellite Co.

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The State of Airborne Inertial-Guidance

Tips on how to get the most performance with the least weight, space, and cost; Why design approach to aircraft navigators is diametrically opposed to missile systems

By Donald Galbraith, Systems Engineer
Lockheed Missile & Space Div.

Unmanned aerospace vehicles must employ automatic systems to replace the pilot and navigator. Requirements of the navigation system therefore follow readily: it must acquire information on the current position and motions, and then calculate steering commands for the projected rendezvous with the target. This latter function entails memory of target location, as well as substantial computation. The main intent of this discussion is to survey the data acquisition problem, not the data processing function.

The System Problem—If vehicle motion is to be measured without external aids (radio, radar, optical, etc.) then recourse must be made to inertial measurement of vehicle acceleration with respect to inertial space.

Assuming, for the moment, that accelerometers rigidly fixed to the airframe will sense acceleration along their input axes, one must note that the set of input axes will rotate with the vehicle. This immediately poses the problem of relating the accelerometer outputs to the fixed-frame of reference in which navigation computations must be accomplished.

Two solutions are available for achieving the body-axis to space-fixed axis transformation: (1) The accelerometers may be isolated from the angular motions of the vehicle by means of a gimballed gyro-stabilized platform; (2) The burden can be thrown upon the data-processing system to mathematically resolve the accelerometer outputs into the fixed frame of reference.

Virtually all present aircraft and missile inertial navigation systems employ the gimbal stabilization method, in spite of the substantial cost in weight of the gimbals, torquers, and associated electronics. The reasons for the avoidance of the bodymounted, or "strapped down" scheme are worthy of note.

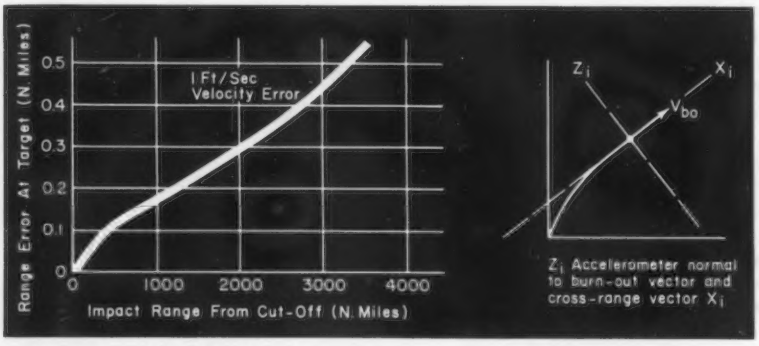

FIGURE 1. RANGE ERROR at target due to speed error of 1 ft/sec at cutoff of rocket engine.

"Strapped Down" Problems—The real time computation problem is staggering in terms of speed required and complexity. Two extensive computations must be made in parallel. The accelerations must be resolved through a full direction-cosine or Euler-angle matrix to transform from body to fixed coordinates. And, secondly, the matrix itself must be updated in real time in accord with angular motions of the airframe, sensed by body-mounted gyroscopes or additional accelerometers. These will sense angular rates in body coordinates again, and must be integrated and transformed into special reference angles. In short, the computation problem is such that the digital computer state-of-the-art only now approaches the speed (microsecond additions) and compactness, needed to make the body-mounted approach feasible.

Stabilized Platform — Consequently, almost every inertial navigator in use today comprises a set of accelerometers mounted on a gyro stabilized platform. The gimbal torquers on the platform drive to zero the angular errors derived from vehicle angular motion. The "critical" accuracy of any inertial system then depends upon the linearity and stability of the accelerom-

eters employed, and the ability of the gyroscopes to "remember" their orientation in inertial space.

Aircraft vs. Missile Systems—The salient difference between the aircraft and missile inertial instrumentation problem is this: The aircraft navigator must function for hours, in a relatively low acceleration field (always close to one "g"). The ballistic missile, however, must be navigated only for the duration of its powered flight. Roughly one to five minutes of burning will cover the 100 to 5000 mi ranges studied here. The acceleration field will be anywhere from 2 to 20 g's on the average. Thus, the aircraft navigator has to contend with long-time accumulations of drift at low acceleration and velocity levels. The missile is faced with precisely the inverse problem. This one consideration immediately tends to slant aircraft systems toward solution of the gyrodrift problem at the expense of the velocity - measurement instrumentation.

Error—Sensitivity of the ballistic missile accuracy to velocity measurement can be noted by reference to Fig. 1. It indicates that at 1500 nautical mile (NM) range, a one ft/sec velocity error along the velocity vector will produce about .25 NM impact error. These statements assume a minimum energy trajectory is flown in all cases. The partial of range error with velocity error is roughly linear with range and indicates that at 6000 NM an error of one NM results per ft/sec burn-out-velocity error. This is just about all of our above-mentioned allowance, and allows nothing for velocity errors in the other two directions or gyrodrift about any of the three axes. The instrumentation problem is worsened by the fact that not only does sensitivity increase with range, but the gross burn-out velocity also increases. Since the error will be proportional to the accelerometer scale factor (error times gross velocity) the accelerometer problem rapidly grows more severe at range.

Accelerometer Basics—Individual accelerometer requirements vary greatly, depending upon the position in which they are used. Crudely, the lateral accelerometer has an error partial about ⅔ that of the principal velocity sensing one (usually the Y_1 and X_1 directions). The third accelerometer (Z_1), which is normal to both the burn-out vector and the laterial or cross-range vector, has about one-tenth the error sensitivity of the X_1 accelerometer. It should be noted that the sensitivities cited are properties of the ballistic trajectory and the burn-out coordinates of the missile. They apply to any object projected into free-fall trajectory at those ranges. Not only must the X_1 accelerometer contend with higher sensitivity, but virtually all the velocity is integrated along that axis. By contrast, the Y_1 accelerometer may not encounter more than a few hundred ft/sec maximum, and these will probably be nulled to zero by burn-out. The Z_1 accelerometer also may have to measure only one to two thousand ft/sec peak velocity, which is ultimately nulled (at max range only). Thus, if the designer elects to orient the accelerometer triplett so that one of them lies along the burn-out velocity vector, he really needs only one very superior instrument. The other two experience small input, only, and the trajectory is not nearly so sensitive in those directions. Consequently a scale-factor stability of 1 in 10^5 is desirable in the X_1 direction, and 1 in 10^4 is more than ade-

	Fluid – Floated	Air-bearing
Single degree of freedom	MIT family: Minneapolis-Honeywell (GG49) Kearfott (2516) A-C Spark Plug Lear, Norden Div. V. A. C. Missile Programs: Polaris; Thor; Zeus; Titan (new)	ABMA series: Ford Inst. Co. Redstone AB-7 Jupiter Eclipse-Pioneer Pershing AB-5
Two degrees of freedom	ARMA Corp: Atlas (all-inertial system) Litton: P3V; A2F; F104 (NATO Powers)	North-American Autonetics: Minute-Man

FIGURE 2. MAKERS AND TYPES of gyroscopes for some current aircraft and missile programs.

Estimated Performance — Characteristics by Classes of Instruments

	Typical Angular Momentum	Estimated Drift Performance (°/hr) (Random Component)			Weight lb	W_o/W_i*
		Static Drift o/hr	Mass Unbalance o/hr/g	Anisoelastic o/hr/g²		
Single deg of freedom fluid—fl	1.4×10^5 cgs units	.3°/hr	.3°/hr/g	.015°/hr/g²	1.0	1:1
Two deg of freedom fluid—fl	1.5×10^6	.03°/hr	.05°/hr/g	.015°/h/g²	2.0	1:1
Single deg of freedom Air-bearing	1.4×10^7	.01°/hr	.02°/hr/g	no data	9.0	10^5
Two deg of freedom Air-bearing	no data	no data	no data	no data	no data	1:1

* Instrument gain: ratio of output axis displacement to input axis displacement.

FIGURE 3. DESIGNERS DATA gives estimated performance for various gyro instruments by class.

Gyros used in pitch attitude control are least critical, azimuth most critical

quate in the Z_I and Y_I directions. Moreover, the X_I accelerometer must achieve this performance at very nearly full scale accelerations while the X_I and Y_I instruments need only achieve it while operating close to zero. Indeed, in aircraft, all three accelerometers will operate at close to null for most of the flight, and null stability becomes more significant here.

Gyroscope Performance — The gyroscopes requirements also follow from trajectory and flight-path considerations. If a ballistic missile is assumed to fly a minimum energy trajectory, then it follows that the sensitivity of range to burn-out velocity vector angle (Y) is zero

$$\frac{2R}{2Y} = 0.$$

(Reference 2). That is

Plainly, this system consideration allows us to place the worst one-third of our gyros in the position which controls platform pitch attitude, or motion about the Y_I axis. Clearly also, error drift in azimuth (about the local vertical or approximately the Z_I axis) is most critical. Conceptually, the angular drift introduced by this gyro times the range, is the error, on a flat earth. The third gyro, that which controls motion about X_I we "rule-of-thumb" as two-thirds as critical as the Z_I gyro.

Weight Costs Range—At least passing note should be taken of the need for space and weight optimization. The basic knowledge for present systems was born in the "Spire Jr." and MIT Instrumentation Laboratory pioneering effort which weighed in at about ½ ton. From judicious system design and instrument improvement, aircraft navigation systems weigh in at about 100 lb today.

In missiles, one pound of inert second-stage weight may cost from 0.5 to 1.5 miles of range. Furthermore, the weight of the guidance equipment may increase geometrically as the weight of the stabilized instruments increases, since these are surrounded by, or supported by, a massive gimbal structure. Currently, the ratio of platform weight to instrument weight ranges from 3.5 to 5.0, exclusive of electronics for servo and computer. Clearly, every modest reduction in instrument size and weight can reflect into vehicle weight, savings of hundreds of pounds.

Component Considerations— Current-state-of-the-art discussions of gyros are embarrassed by the fact that most data is classified, and most of what is left is considered "proprietary information." Nevertheless, certain conclusions about classes of instruments can be reached. Inertial gyros currently in use fall into natural categories according to their gimballing and flotation arrangements. We can divide this universe into fluid-floated and gas-suspended instruments, and single degree-of-freedom versus two-degree-of-freedom gimballing. Fig. 2 lists typical manufacturers and weapons in which these are currently employed. Fig. 3 is the estimated typical performance for each class of instrument.

Principles Of Design — All of the gyro designs of inertial quality have had to find the means to float or suspend the gyroscopic element in a fashion which unloads the bearing from reaction forces. The rotating mass is conventionally sealed inside a float or can, which must then be pivoted, gimballed, or suspended in a way that will define to the gyro, the input and output axes. These are the axes about which angular motion is detected (input) and about which an indication of motion is provided (See Fig. 4).

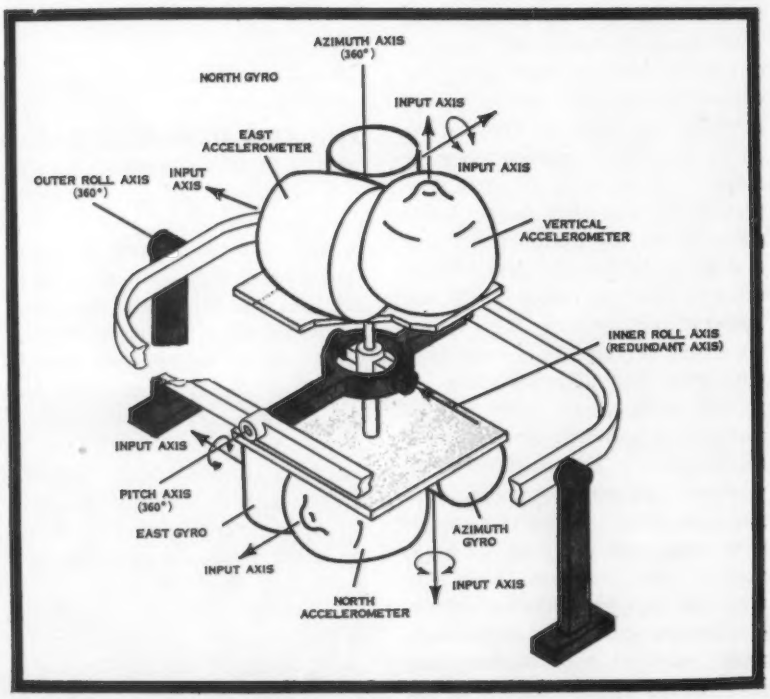

FIGURE 4. INERTIAL PLATFORM schematic for "pure" inertial system shows 3 accelerometers, 3 integrating gyros, 4 gimbals. Minn-Honeywell's GG44 platforms use this layout. Fourth gimbal is redundant.

Single Degree Of Freedom—In a typical single-degree-of-freedom gyroscope (Fig. 5) the float (containing the gyro) is pivoted so that an input angular motion will actually apply a torque to the gyro and cause precession about the output axis. If no flotation fluid were present, the gyro would precess rapidly until the input torque was removed.

In addition, all the weight load of the float would be borne by the pivots. Consequently, the frictional reaction forces about the output axis would vary with the level and direction of the translatory acceleration of the gyro. In all fluid-floated instruments it is common practice to fill the volume between the float and the case with fluid. This serves two purposes: one, it suspends the float inside the can, provided the specific gravity of the float matches that of the fluid. Two, it can also provide viscous damping of the instrument. Viscous damping essentially reduces the gain of the instrument to around unity. In practice, the output displacement of the spin reference axis (SRA) is restored by the action of a gimbal servo, which helps to define the requirements upon the servo in systems using one degree of freedom (DOF) gyros.

It will be noted that nothing mentioned so far has indicated any advantage in building these gyros in large sizes to obtain good theoretical performance. Indeed, this class of instrument lends itself to small size and weight, as seen in Fig. 5.

Since it is necessary to precess the SRA in order to obtain any output, the dynamics of the gyro and gimbal torques must be designed jointly. It is very desirable to keep output excursions of the gyro small, to avoid sensing motions about axes other than the original input axis and to avoid undue sensitivity to "coning" effects (Reference 3), where circular or conical vibratory inputs are encountered. For this reason, geared-gimbal torquers are usually avoided due to inevitable gear chatter which could produce coning by itself.

Fairly large direct-drive torquers are then required for this class of instrument, which sacrifices some of the size and weight gained.

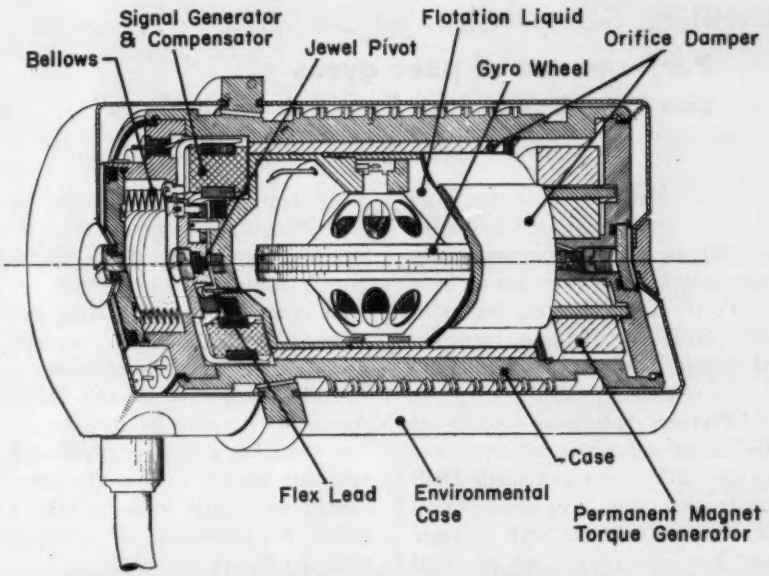

FIGURE 5. MINIATURE INTEGRATING GYRO (MIG) shown uses paddle damping and PM torquer. Minn-Honeywell is manufacturer.

Since one design objective of this class of instrument is to achieve damping by viscous means, the ratio of viscous drag force (D) to angular momentum (H) must be large. This means in practice that H will be relatively small, since realizable viscosities are limited. For these reasons a figure of about 100,000 to 250,000 cgs units of momentum seems to be typical. Unfortunately, the smaller H, the greater is the error drift for a given error torque. This design seems to be peculiarly susceptible to mass-unbalance torques. The multiple problems of causing the center of gravity of the float to coincide with the center of buoyancy of the fluid, are aggravated by the cost and difficulty of disassembling the instrument to rebalance. Bubbles trapped in or liberated from solution in the flotation fluid cause slowly migrating mass shifts which defy compensation.

Two Degree Of Freedom—The two DOF gyro avoids certain of the problems in exchange for others. In the two DOF instrument, an extra gimbal ring and bearing are added, so that angular motions about the two axes normal to the spin axis and to each other will not precess the gyro. This is just the familiar free gyro with flotation. Of course, only two gyros are needed per platform instead of three single DOF. Since it is desired that the spin reference axis not move in the presence of angular input motions, the designer endeavors to maximize H/D, using low-viscosity-fluid and all the momentum he can afford. Representative values of H tend to be about 10 times greater in this instrument and error drifts substantially lower. The instrument tends to be heavier (but not larger) than competing single DOF fluid-floated gyros. Lower viscosity fluids are probably easier to fill without entraining bubbles. On the opposing side of things, careful balancing is required about two axes. Since the SRA is not precessed, coning effects are not serious and geared torquers can be used. Also, the cross-coupling effects described above for single DOF instruments do not occur.

Both kinds of fluid-floated instruments have some common problems. Since both must meet specific gravity requirements in the float, the designer must compromise the amount of weight at his disposal, between increased momentum and

Performance of poor gyros can be enhanced by "pendulous devices"

increased rigidity. The latter is an aid in overcoming compliance, or anisoelastic effects, wherein certain vibratory input motions are rectified into error drift. Since the two DOF gyro profits mostly from increased H, it suffers more from susceptibility to anisoelasticity.

Problem Solutions—Certain of the above difficulties are overcome in the ABMA series of single DOF air-bearing gyros. In these units, there is no fluid but high pressure air. The inlet orifices are arranged to produce self-leveling and centering of the floated cylindrical can. Since there is no specific gravity matching problem, the designer can make wheel inertia and can structure suitably rugged and/or heavy. Without fluid, there is no need for sealing, and there is access to the suspended element while operating, if desired, for precise mass balancing. Essentially, mass unbalance may be trimmed far below the data cited in Fig. 3, and anisoelasticity is nil. Elimination of fluid not only removes certain mass-unbalances and allows larger momenta in the same size unit, but it makes for logistic simplicity as well.

On the debit side of the ledger, it must be noted that an air supply is required for these units and that fairly severe filtering is needed to prevent contamination. This latter consideration probably limits their present use in very long time applications. In addition, all damping must be supplied by the electronic servo system, although again, geared torquers can be used in view of the very large H vector which is 10 times greater than that of the two DOF gyros above. In general, air-bearing gyros have been conspicuously successful in the Army ballistic missiles and space boosters. They appear to be the most precise and reliable units in service today. It should be noted that the size and weight of these units (AB-7 gyros) is substantially greater than that of competing units, and good platform system design is needed to keep the gross platform size competitive.

Concerning the air-bearing two degree of freedom gyro, security precludes more than brief mention. In this class we find the G-6 North American Aviation Autonetics series which has a dynamically floated spin-axis, rather than a statically-floated output axis, as in the ABMA series. No experience or performance details are available.

Accelerometer Details—Accelerometers present a more clear-cut picture. In unclassified literature, two classes of them can be discussed. The force-balanced pendulum, and the pendulous integrating gyro accelerometer (PIGA). Reference 1 contains a good account of the operating principles of each. The force-balance pendulum simply detects the displacement due to input acceleration of the sensing pendulum and provides a magnetic torque to restore the pendulum almost to null. The restoring current is then a measure of input acceleration. The full-scale factor stability of the best of these instruments is somewhat better than one part in 10^4 and accuracy is probably limited more by the ability to measure currents precisely than by any other single factor. Accelerometers of this type are produced by several firms and have the salient virtue of small size and weight. Characteristically, they are rectangular in shape (about 1 x 1 x 2 in.) and weigh about ½ lb.

Pendulous Gyro — If better accuracy is desired, the pendulous gyro is available. In this device, a single degree of freedom gyro is deliberately unbalanced to produce an input torque along the desired axis. The entire gyro is rotated about its input axis to produce a precessional torque which balances the unbalanced torque. The angular rate is proportional to input acceleration and the total angle rotated is proportional to elapsed velocity, the first integral of acceleration. Judicious use of scale factor and pendulosity allow rather poor gyros to make very good accelerometers, and 5 parts, per 100,000 is not difficult to achieve in scale factor stability. The price is size and weight. A one-pound gyro two inches or so in largest dimension makes up into 8 lb PIGA as big as a Mason jar. This is due to the need for a volume of revolution, as well as a trunnion and torquer, pick-offs, and amplifiers. A shaft encoder is also required. Three such large accelerometers will, of necessity, make a large platform no matter how ingenious the designer. Consequently, one is well advised to employ the PIGA only in the most critical direction, but freedom to do this requires that the stable member has the ability to be accurately "aimed" in the intended direction. This aiming calls for precise instrumentation of the stabilized gimbal, or for optical access, or both, if you work it right.

Light Platforms — In general, aircraft and certain shorter range missile - applications can employ three of the small force-feedback accelerometers. This allows the designer of the system some priceless chances to reduce platform weight. Certain platforms with small accelerometers and light-weight fluid gyros are available at 30 lb, plus electronics. If three PIGA's are required, by way of contrast, you will be lucky to do it for 140 pounds, using the same gyros.

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The Swing to Tilt-Devices For Gyro Testing

Earth's gravity vector can be used for precise acceleration inputs; Centrifuge tests may be eliminated

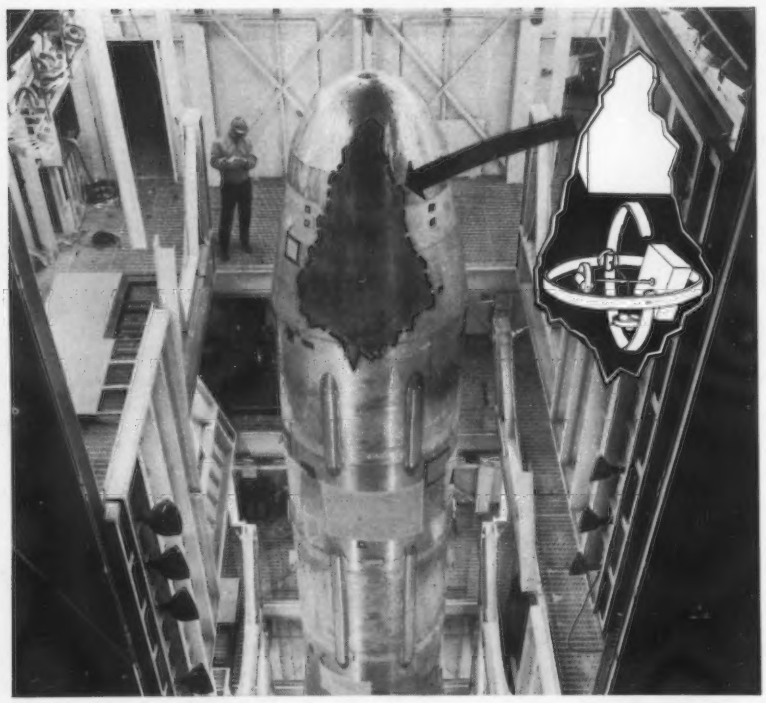
By George E. Sonntag, and John L. Perample,
AC Spark Plug Div., General Motors Corp.

Inertial guidance aims a missile during acceleration, and cuts off the power when the speed necessary to hit the target has been reached.

Every inertial guidance system consists of two principal elements:

- A sensor — which measures missile motion to an accuracy of one part in 100,000.
- A computer—which calculates velocity from the sensor information, then compares and adjusts it with velocity needed to hit the target.

A sensing error as minute as 1 ft/sec out of a 24,000 ft/sec velocity at power cut off will result in a miss of one mile at the target. Still, inertial guidance systems have the accuracy to transport a payload from New York to Los Angeles. This reflects the precision that is built into sensing devices and the exactness of test methods and devices which must be used to inspect them before they are installed in a missile. The test fixture must be better than the device being tested.



PRINCIPAL ELEMENTS of inertial guidance system are sensing accelerometers and computer. Pendulous gyros described in this article are used in accelerometers at X, Y, and Z.

Acceleration From Gravity Vector—At AC Spark Plug's Milwaukee plant where the inertial guidance system for Titan is built, a new method for testing gyroscopes is being used. The gyroscopes are of the pendulons type and are used in the integrating accelerometers.

Accelerations of known value must be applied to the gyroscopes during testing. The conventional method of generating these accelerations has been to use a centrifuge. The new test, however, is based on placing the gyro in a special test fixture which can be tilted in such a way that the natural gravity vector causes an acceleration input.

Tilting has a maximum input value of 1 G. Centrifuging is limited in G input only by the capacity of the centrifuge mechanism. The tilt method, however, is preferred for production tests even though the accelerometer must detect much high forces in the missile. Reasons for favoring the tilt method are:

- Steadier input, and more easily controlled and repeatable input.

●Gyroscope errors are more easily analyzed. Most output errors are constant or sinusodial function. These are more significant at low inputs.

● Output is proportional to input at all levels (except for errors) since the device is null-operating. Saturation types of nonlinearity do not exist.

Test Stand Design — A gimbal which is free to rotate on stanchion supports is incorporated in the new testing stand. The tilt, or acceleration input, is applied to this gimbal (Fig. 1). The gyro being tested is placed in a cavity of the input axis shaft of the test stand. The shaft is driven by a d-c torque motor at one end and the shaft position, or rate, is measured by a 7-in. diam resolver at the other end.

One of the design problems of the stand was, naturally, how to achieve the extreme accuracies required in gyroscope testing. The fixture was not to introduce more than 1 micro-radian per second error in finding the angular rate of rotation of the input axis ω. This implied that the following operational accuracies of the fixture would be necessary:

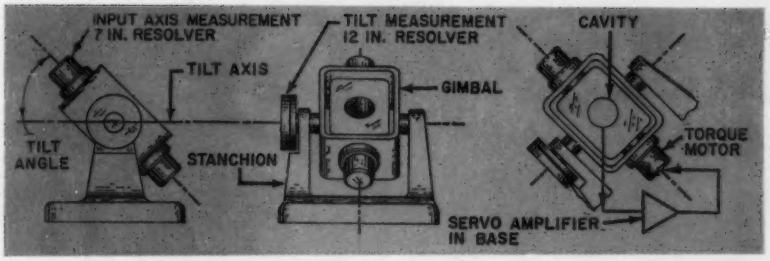


FIG. 1. TILTING DEVICE accommodates gyro to be tested in center cavity. Gimbal rotates on stanchion supports. Tilt shaft is driven by a DC torque motor.

● Tilt axis measurement to be accurate to 0.5 sec and repeatable to 0.25 sec.

● Angular rate measurement to be accurate to 1.2 angular sec per revolution.

● Time interval per revolution to be accurate to 10^{-5} seconds.

● The servo loop to maintain the pendulum of the gyroscope within 1 sec of perpendicularity to the input axis.

Largest Obstacle—An important phase of the design, therefore, was a study of angular measurement. Mechanical techniques proved basically inadequate, and the search was concentrated on optical and electronic techniques. These utilized frequency differential, phase shift, capacitance change, light interferometry, magnetic tape, and spectroscopy. Accurate angular measurement proved to be the largest obstacle in developing the best device.

The method chosen for both tilt and rate measurement in the test stand was the use of an electrical resolver with single-turn wind-

● ——— ABOUT THE PENDULOUS GYROSCOPE

An integrating accelerometer displays its output as a function of output shaft position. This shaft position is usually measured by a potentiometer coupled to the output shaft.

The accelerometer contains a complete independent servo loop which integrates the input accelerations. In this loop the instantaneous rate of the output shaft is a measure of the instantaneous acceleration. The linear acceleration is proportional to angular velocity. Linear velocity, therefore, is proportional to the angular position.

The gyroscope is constructed so that a pendulous mass produces a torque about the output axis of the gyroscope when it is accelerated in the direction of the gyroscope *input axis*. This torque can be counteracted by rotating the gyroscope about its input axis. This is accomplished by a servomotor, K_M (Fig. 2).

The basic equation for equilibrium of this system is:

$$Ml\alpha = H\omega$$

where

Ml = (mass) (moment arm) = pendulosity

α = acceleration in direction of gyroscope input axis

H = gyroscope wheel momentum

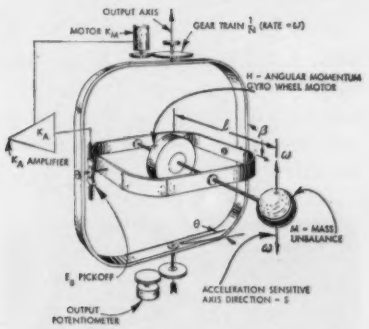
ω = angular rate of rotation about the input axis.

Since M, l, and H are constants, the rate of rotation, ω, is proportional to input acceleration α, and the instantaneous velocity, in the direction of the acceleration, is proportional to the angle through which the gyroscope is rotated about the input axis.

Therefore:

$$\text{Velocity about input axis} = \int \alpha \, dt$$

$$\text{Angular rotation } \Theta = \int \omega \, dt.$$



PENDULOUS GYROSCOPE is used in accelerometers. Drawing shows the gyro and servo loop which integrates input accelerations of the missile.

AC Spark Plug's tilt-stand device uses electric resolvers for angular measurements

ings etched in two glass plates to form the stator and rotor (Fig. 2). The extreme accuracy with two resolvers is the result of the precise dividing of the windings on the glass and the averaging effect of multiple series windings. This averaging effect also makes the resolvers insensitive to small mounting eccentricities.

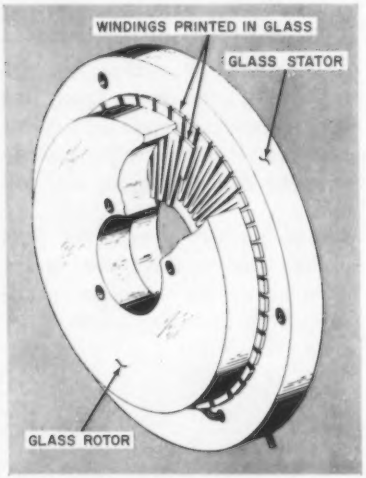


FIG. 2. TWO ELECTRICAL RESOLVERS are used for angular measurements: 12-in. diam, 360-pole resolver for tilt, and 7-in. diam for rate.

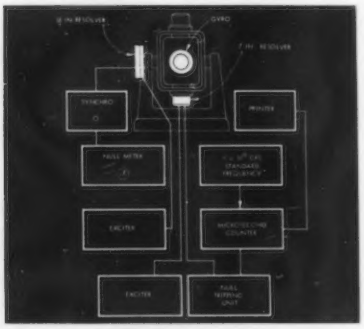


FIG. 3. RELATION OF COMPONENTS for tilt angle measurement and rate measurement system are shown. Printer gives info from 7-in. resolver.

A 12-in. diam, 360-pole resolver was chosen for the tilt measurement device and a 7-in. diam, 360-pole resolver was chosen for the rate measurement. Both had an angular accuracy of 1 sec of one degree. The resolver generated a sine and cosine function for each 2 deg of rotation. This sine and cosine function from the 12-in resolver was then further divided into ¼-sec angles by a synchro on a console associated with the test stand. The 7-in resolver output triggered a time counter and digital printer (Fig. 3). This provided a reading of time in microseconds for each 2-deg rotation of the input axis.

Manufacturing Demands—The machining tolerances necessary to produce a fixture compatible with the test requirements required special attention. Some of the areas considered were: (1) gimbal orthogonality, (2) resolver mounting, and stanchion alignment.

The orthogonality requirements of the gimbal bores were not severe. The tilt angle error is a function of the cosine of the angle of non-orthogonality. Thus, a boring error of 5 min will result in 0.1 sec of tilt error. Using optical setups, the boring error can be held to less than 1 min.

The cone of wobble in the input axis shaft would be seen by the gyroscope as a sinusoidal change in tilt angle input. In the assembly of the completed test stand, this cone of wobble was reduced to an angle of one second by aligning the high eccentricity points of both the inner and outer races of the class 7 duplex bearings.

Concentricity and parallelism of the output shaft bearing assembly were held to 0.001 in., by making the input axis shaft in three pieces. The gimbal also is a three-piece assembly with the main casting bored through and two precision stub shafts bolted to it. These accuracies are required not only for controlling tilt angle position, but also for reducing the bearing friction and friction variation to a minimum.

Component Selection — Gyroscope friction will affect output and reflect in the table rate as disturbances. Unfortunately, the recorded rate data do not discriminate between gyroscope transients and test stand disturbances.

The slip ring and brush assembly used on the test stand has a uniform frictional drag because of the averaging effect of 72 brush contacts backed up with "soft" springs. Since the brush contact friction is about five times greater than the bearing friction, the total friction is about 3 in.-oz while the brush friction is about 15 in.-oz. These slip rings and brushes, are standard parts made by AC Spark Plug for other systems. The parts were chosen because of their very low electrical noise level.

The d-c torque motor, which drives the input axis shaft, develops a torque of 75 in.-oz at 25 per cent overload. Therefore, with a running torque of about 10 in.-oz, the motor has sufficient torque available for the high response necessary to maintain a tight servo loop.

The choice of the d-c, torque motor gearless direct drive, instead of an a-c servo motor with a gear train, has several advantages. Under production testing, the gear train developed backlash and was a cause of instability in a tight servo loop. The d-c torque motor with its back emf acts as an inertial damper and helped stabilize the loop.

The servo amplifier driving the d-c torque motor is a transistorized design and is mounted in the base of the stand to reduce the length of gyroscope output wiring.

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Rocket Engine With Throttle

Aerojet's sled-driving, liquid engine paves way for versatile space applications; System sophistication attained through simplification

By Philip Geddes

A variable thrust rocket engine was recently delivered to the Air Force by Aerojet General, Sacramento. Its mission is strictly earthbound on a sled, but the future for such engines is in space and possibly in anti-missile missiles. The XLR113AJ1 engine is capable of stable performance from 50,000 to 150,000 lb of thrust. Hypergolic, storable unsymmetrical dimethyl hydrazine (UDMH) and nitrogen-tetroxide (N_2O_4) are the fuels used. Mixture ratio is 2.2 to 1, oxidizer and fuel, by weight. These fuels have high specific impulse (230 sec), good impulse - density ratio, are relatively insensitive to mixture ratio variation, and are not corrosive. It has been suggested that much larger engines can be derived from the design.

Desirable for Space - Applications—Variable thrust feature offers the advantage of controlling "g" loads on structure during flight. Thus, stress limits can be held, allowing design of optimum structure; soft landing problems are simplified; reliability improves with clustered variable thrust engines; and in the clustered application power loss in one unit can be compensated for by increasing the thrust of others.

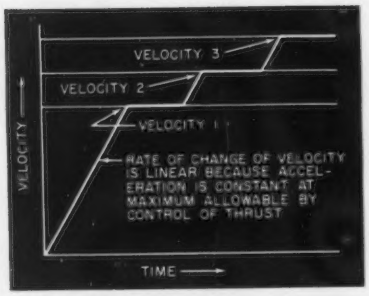
This engine, however, is not intended for an exotic space function; it is designed for a very down-to-earth job. Reliability on a daily use basis year round, control sensitivity, and repeatability are built into the engine. Some sacrifices of weight could be made, but with one eye on the future, concessions were held to a minimum.

Why Variable Thrust for Sleds?—Sled runs are programmed to simulate various phases of a missile trajectory (among many other functions such as testing: flutter in control surfaces, jet engine reverse thrust schemes, escape systems, etc.). In this way, components can be evaluated and calibrated under high linear velocity and "g" loadings. Test runs can be repeated many times and in the critical ranges for individual components until all the bugs are ironed out. Obviously any run must be repeated accurately and economically as possible.

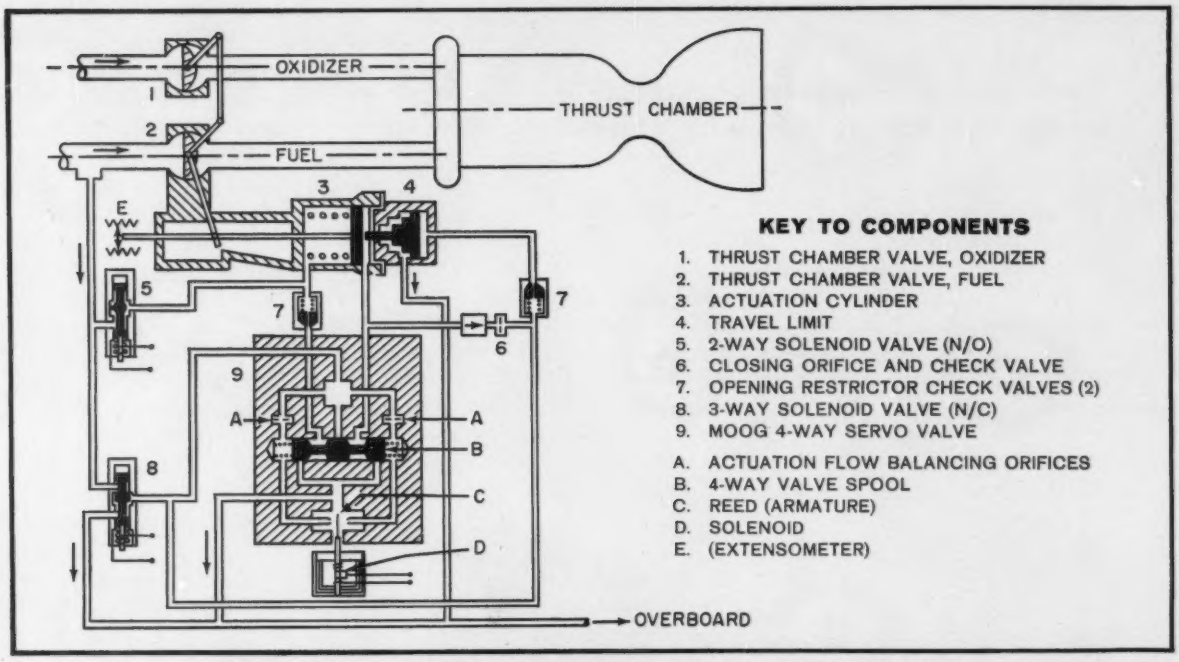
Sled versatility, as far as an engine is concerned, has to be greater than in a missile with one trajectory. A sled engine must satisfy requirements of many different trajectories. When a sled is sent down a track, aerodynamic drag increases rapidly with velocity rise and total weight decreases rapidly as fuel is burned off, acceleration varies accordingly. These factors must be accounted for in calculating loads on components under test. Often, data required for a particular set of conditions can only be acquired for a instant. Great ingenuity has been put into sled propulsion systems to enable the maximum amount of data for a single run. Clusters of sixty solid-rocket units have been fired. "As many as eleven stages have been fired in a single test to provide critical vernier control of acceleration. Coordinated firings of solid propellant rockets and liquid propellant rockets are sometimes made in order to exploit the advantages of each."—Quota-

XLR113AJ1 OPERATING DATA

Thrust, Nominal	150,000 lb
Duration, Nominal	10 sec
Total Impulse	1,500,000 lb-sec
Specific Impulse	230 sec
Mixture Ratio	2.2
Oxidizer Flow Rate, Nominal	448 lb/sec
Fuel Flow Rate, Nominal	204 lb/sec
Total Flow Rate, Nominal	652 lb/sec
Chamber Pressure, Nominal	600 psia
Propellant Tank Pressure	800 psia
Gas Tank Pressure	2750 psia


VELOCITY 3
VELOCITY 2
VELOCITY 1
VELOCITY
RATE OF CHANGE OF VELOCITY IS LINEAR BECAUSE ACCELERATION IS CONSTANT AT MAXIMUM ALLOWABLE BY CONTROL OF THRUST
TIME

THREE LEVELS of test data may be obtained by rocket sled using variable-thrust engine; overall testing costs would be cut to about ⅓, compared to three separate runs.



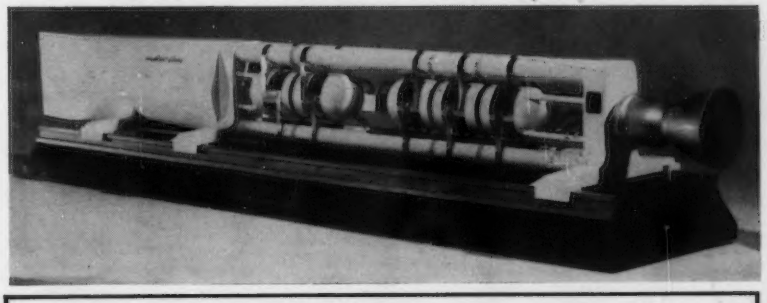
PROPELLANT VALVES governed by control system give XLR113AJ1 engine variable thrust from 50,000 to 150,000 lb.

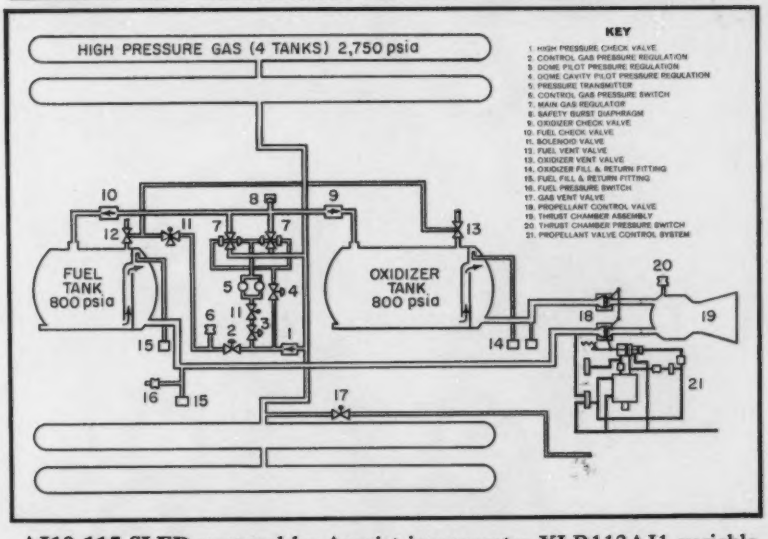
tion from Edwards AFB high speed track brochure.

With a variable-thrust propulsion system, compensation can be made for decreasing weight and increasing velocity. "G" level can be easily adjusted so that test conditions can be held where desired for sustained periods. At a given velocity, the engine thrust can be set to maintain speed where drag and thrust are in equilibrium. Steady-state data can be obtained under say three different velocity levels during a single run. Versatility in sled performance improves considerably to the point where it is believed that more can be achieved with fewer runs.

Design Problems — Basically, thrust variation can be achieved by varying any one of the following: (1) nozzle area, (2) injector orifices, (3) inlet pressure to injector (with a pump or a valve).

In the XLR113AJ1 engine installation proposed for Aerojet's AJ10-115 sled, four high-pressure tanks keep a pressure head on the fuel and oxidizer. This arrangement dispenses with the need for a high-





AJ10-115 SLED proposal by Aerojet incorporates XLR113AJ1 variable-thrust engine, shown here in model and schematically.

Titan's propellant valves adapted using seals compatible with storables

speed pumping system. Thrust is varied by a valve controlling propellant inlet pressures at the engine. The inherent problem in such a system is to maintain stability in the injectors and keep fuel tank pressures low. Design problems at the injection end are certainly simplified if tank pressures can be allowed to rise to 2000 psig. But, if wide future applications were to be incorporated into the sled engine design, high pressures could not be tolerated. Stability problems were overcome with 800 pisia pressure in the propellant tanks. Two Aerojet pressure regulators feed gas from the high-pressure tanks at approximately 50 lb/sec into the propellant tanks. These valves keep liquid pressure at the thrust-chamber injector constant within close tolerances from start to burnout.

THROTTLABLE rocket-engine combustion chamber, made of 300 series stainless, is film cooled.

Combustion Chamber—Regenerative combustion chamber cooling is difficult in a variable thrust design since flow varies with thrust level. So, the design group went to a film-cooled chamber, where the cooling-fuel flow is in parallel rather than in series, giving a constant rate of fuel coolant at all thrust levels. High strength in excess of expected operating stress levels was important as the sled would be handled daily over a long period of time. This engine was to be strictly a working tool and not a delicate one-time prime mover. Series 300 stainless steel for the combustion chamber was chosen to withstand repeated use without hardening.

Components — The main propellant valve and certain other hardware were taken directly from the Titan power plant. The valves are of aluminum alloy construction with stainless steel gates and spindles. In most cases, the only changes needed for adaptation were in seals for use with the storable fuels. Henry Ford's philosophy of tell me where I can take things off this engine, not put them on, was the catchword of simple design philosophy for the project. In line with this thinking, simple hydraulically-operated mechanical controls with simple linkages were designed.

Designers of the engine state that the engine was built to do a specific job in a specific location. The design philosophy used in solving such problems as throttling and instability, film cooling, and doing a complex job with a minimum number of parts can be applied to any future engine.

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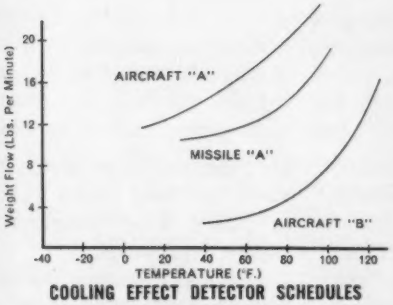

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AN EXPERIMENTAL METHOD FOR . . .

Evaluating Honeycomb Bond Quality

Pulsed-Wave Technique Using Surface-Type Waves Traces Telltale Signal on Cathode-Ray Tube; Increase in Peak-To-Peak Signal Amplitude Earmarks Bond Areas of Poor Quality

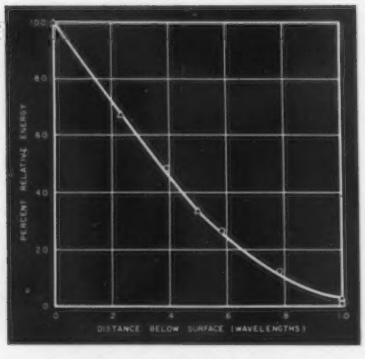
by E. T. Hughes, Materials Engineering and E. Burstein, Materials & Standards
Westinghouse Electric Corp.

Evaluation of bond quality in honeycomb sandwich structures has been based mostly on arbitrary techniques. The lack of simple and reliable methods of nondestructive testing has confined use of such structures to non-critical areas.

When the Air Arm Div. of Westinghouse began using honeycomb sandwich from outside sources, a uniform inspection procedure became mandatory. Consequently, a program was undertaken to evaluate the available inspection techniques and instruments. An initial analysis ruled out the attenuation (continuous and pulsed-wave types) and resonance methods of testing. This was because aluminum cell thickness of 0.003 in. or less could not transmit energy properly, in frequency ranges considered. Cell wall-thickness and cell spacing precluded use of reflection type tests. Further study narrowed down the search to pulsed wave technique, using surface type waves.

Normally, surface waves travel with negligible attenuation in their direction of propagation. However, their energy decreases rapidly as waves penetrate below the surface to a maximum depth of 1 wave length. The generally accepted energy depth relationship is shown

FIG. 1. RELATIVE ENERGY OF SURFACE WAVE vs DISTANCE BELOW ENERGY



(Cook and Van Valkenberg)

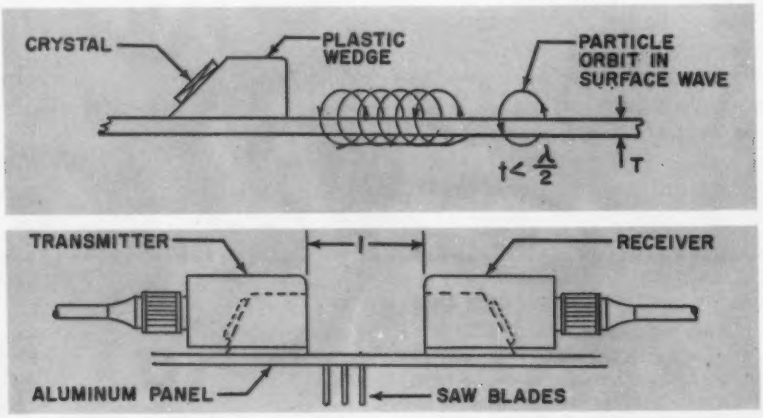


FIG. 2. SURFACE WAVE propagation is illustrated schematically (above), with experimental search unit arrangement used (below).

in Fig. 1. It is known that in surface-wave testing of sheet material less than one wave length in thickness, some energy will travel along the underside of the sheet and along surface contacted by the search unit. Previous experience showed that the amount of energy available on the underside of sheets greater than ½ wave length in thickness is insufficient for test purposes; (for aluminum sheet the limiting thickness is about 1/16 in. at 2¼ megacycles). In this thickness range, the sound waves produced in the sheet may not be true surface waves but rather some form of Lamb waves.

In the surface wave mode of testing, the sound energy is confined to a narrow region on and just below the surface of the material being tested. This surface energy can be reduced or damped by placing a sound attenuating substance in contact with surface in the path of the beam. A damping effect should likewise be producible on the underside of the sheet less than ½ wave length in thickness. This latter damping effect was used in developing a test for detecting unbonded sections of the honeycomb.

Preliminary Experiment — Extent of damping effect and practicality of this phenomenon were determined by a simple experiment. A 0.030-in. thick 2024 T3 Alclad aluminum sheet was clamped in a fixture so that both the top and underside were accessible. Two 2¼ mc surface-wave search units were connected to a Sperry Type UR Reflectoscope so that one acted as a transmitter and the other as a receiver, as in Fig. 2. Search units were coupled to the top of the sheet through a film of SAE 20 lubricating oil. The amplitude of the signal on the cathode ray tube, of the test instrument, was then set at 3¼ in. peak to peak; the signal indicated the amount of energy transmitted along the sheet to the receiver search unit.

The smooth edge of a hacksaw blade was then placed in contact with the underside of the aluminum sheet between the two search units as shown in lower sketch of Fig. 2. A decrease in amplitude of the received signal was noted. Up to five saw blades were then placed in contact simultaneously with the underside of the sheet in area between two search units. In turn, the amplitudes of the received energy-signals were noted. Reflectograms in Fig. 3 show the typical screen patterns obtained. Two plots (different search unit spacings) of the signal amplitudes obtained versus the number of saw blades in contact with the underside of the sheet are shown in Fig. 4. A proportionate drop in signal amplitude with increasing number of blades coupled to the sheet is clearly evident in these curves.

In the preceding experiment, edges of saw blades were placed normal to direction of sound-beam propagation. In a second series of experiments, the angle in the plane of the sheet between saw blades and direction of propagation was varied; amplitudes of received signals were again noted. Varying the angle between 90 and 45 deg to the direction of sound propagation did not have much effect upon the amount of energy received. Test results for all angles between 90 and 45 deg were essentially the same as those in Fig. 4. Significance of these results becomes evident when the shape of the honeycomb cell is noted and the angulated edge contact with the underside of the face panel is considered.

For experimental purposes, sample honeycomb panels were made up by the Air Arm Division. One panel was bonded using the best bonding techniques and optimum curing procedures for adhesive bonding. A second panel was bonded under the same curing conditions as the first, except that in a specific area a strip of film adhesive was cut out prior to bonding. Another area in this second panel was made with the bonding medium thinner than usual; this was done by thinning the adhesive film with solvent. In Fig. 5 are shown the panel areas in which the thinned down adhesive was used, also where

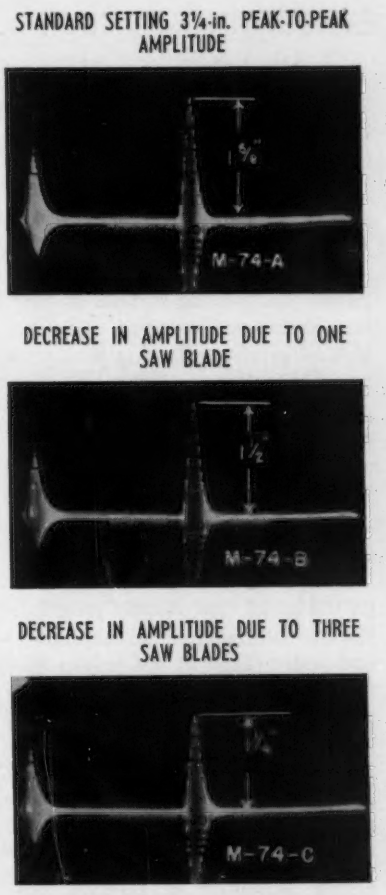

STANDARD SETTING 3¼-in. PEAK-TO-PEAK AMPLITUDE
M-74-A
DECREASE IN AMPLITUDE DUE TO ONE SAW BLADE
M-74-B
DECREASE IN AMPLITUDE DUE TO THREE SAW BLADES
M-74-C

FIG. 3. REFLECTOGRAMS show change in signal amplitude due to increase in number of saw blades coupled to underside of aluminum panel.

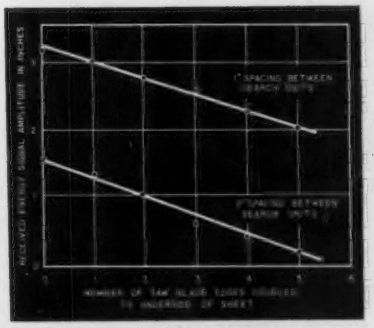


FIG. 4. DROP IN RECEIVED ENERGY signal amplitude is evident with an increase in number of saw blade edges coupled to underside of aluminum sheet.

Visual inspection after peel tests shows correlation of actual and ultrasonically indicated conditions

no adhesive was used. A third panel was purposely undercured; on this panel, the bonding surface of both face sheets was oxidized due to a lack of priming. Testing personnel were only informed that the first panel, identified as "A," was a good panel and that the other two, identified as "B" and "C," were defective.

All three sample panels were examined ultrasonically, using a technique similar to that devised for the initial experimental program. Because of higher signal amplitudes and wider range of test results obtainable, a search unit spacing of 1 in. was maintained throughout the tests. Testing sensitivity was established by properly positioning the two search units on a sheet of aluminum having same thickness as face panels of the samples, and adjusting amplitude of received energy-signal to 3¼ in. peak to peak.

Both search units were clamped together, then placed on face panel of samples to be tested. Again, the couplant was a thin film of SAE 20 oil. The combination search unit was moved on the surface of the face panel in 1 in. steps, noting the amplitude of the received signal at each step. Using the amplitude readings recorded on the good panel "A" as a basis, arbitrary limits were set up to differentiate between "good," "poor," and "no bonding."

The following method was used for recording ultrasonic test results:

Signal Amplitude (inches)	Numerical Rating	Quality Level
¼ in. and Smaller	1	Excellent
¼ to ¾ in.	2	Good
¾ to 1¼ in.	3	Border Line
Over 1¼ in.	4	No Bond

In panel "B," the most obvious indications of poor and no bonding were recorded. Areas in which these two conditions were believed to exist are shown in Fig. 6. Signal amplitudes found in panel "C" were slightly above the arbitrarily set borderline, and the bond was considered of poor quality. Detailed test results on panels "A," "B," and "C" are shown in Fig. 7.

The three sample panels were then sawed into 2-in. wide strips and destructively tested using the Climbing Peel Test as outlined in MIL-STD-401A. On panel "A," the average peel strength was 114 lb. Panel "C" exhibited a relatively low average value of 77 lb. In the unbonded areas of panel "B," as determined ultrasonically, peel strengths ranged from 80 to 105 lb; in the good areas the strengths were comparable to panel "A."

At first glance, the correlation between ultrasonic test results and peel strength values does not appear to be very good; that is, the areas rated as "poor" in panel "C" had lower peel strengths than those rated "no bond" in panel "B." A probable explanation for this anomaly lies in the fact that there was adhesive primer over the areas in which the resin adhesive was cut away on Panel "B." Under pressure and heat the primer probably flowed and created a better bond, though intermittent, than was obtained between the adhesive and the unprimed oxidized faces of panel "C." Another explanation may be that the two-inch peel-test specimens only had one inch of void area. However, the results of visual inspection after destructive testing were in close agreement with sonic test results. In panel "B," the area rated as "no bond" actually was not bonded. The similarity in contour of the unbonded area to that rated "no bond" ultrasonically is clearly shown in Fig. 8. Examination of panel "C" after peel testing revealed that the panel was poorly bonded as was indicated by the surface wave test—failure or separation occurred between the face panel and bonding medium whereas in the well-bonded areas of panels "A" and "B" separation occurred within the bonding medium.

Conclusions — Test results obtained in the preliminary experiments with saw blades indicate: (1) that energy does travel along the underside of an aluminum sheet subjected to surface wave testing; (2) that this energy will be damped proportionately with the number of edges placed in contact with the underside of the sheet. This information was then directly applied to the ultrasonic testing of honeycomb panels with the supposition that the higher the number of cell edges in intimate contact with the face panel, the greater the attenuation of the sound beam. Indication

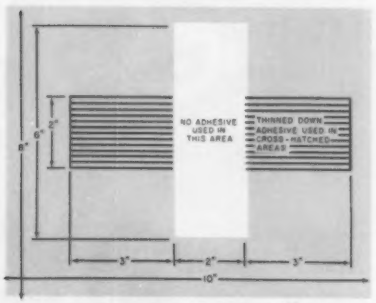


FIG. 5. SAMPLE PANEL "B" incorporated an area with thinned down adhesive, and one without adhesive.

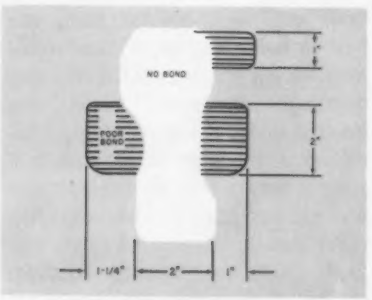


FIG. 6. ULTRASONIC DEFINITION of relative sizes and locations of "poor bond" and "no bond" areas are mapped on panel "B."

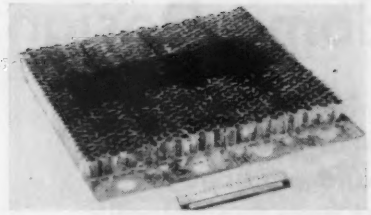


FIG. 8. PANEL "B" photograph, taken after destructive testing, reveals similarity of contour of unbonded (dark) area to that determined ultrasonically.

of good bonding would, therefore, be a signal of low amplitude. Test results on the few sample panels investigated substantiated this theory.

There are sufficient differences in signal amplitude, between the extremes of good and no bonding, to permit evaluation of bonding quality. However, directional differences in honeycomb construction cause considerable scatter in results in any direction other than perpendicular to the ribbon of the core.

In this experimental program, most of the testing was confined to one size and type of honeycomb, which was adequate to determine feasibility. To develop the full capabilities of the surface-wave test, additional work is needed to measure the effects on testing sensitivity produced by varying the thickness of the face panels as well as changing the test frequency. Variations in search unit sizes and configurations should be studied to permit the testing of curved and compound-surfaced honeycomb panels. Also, bonding mediums other than the adhesive used should be evaluated for differences in attenuation which may affect testing sensitivity.

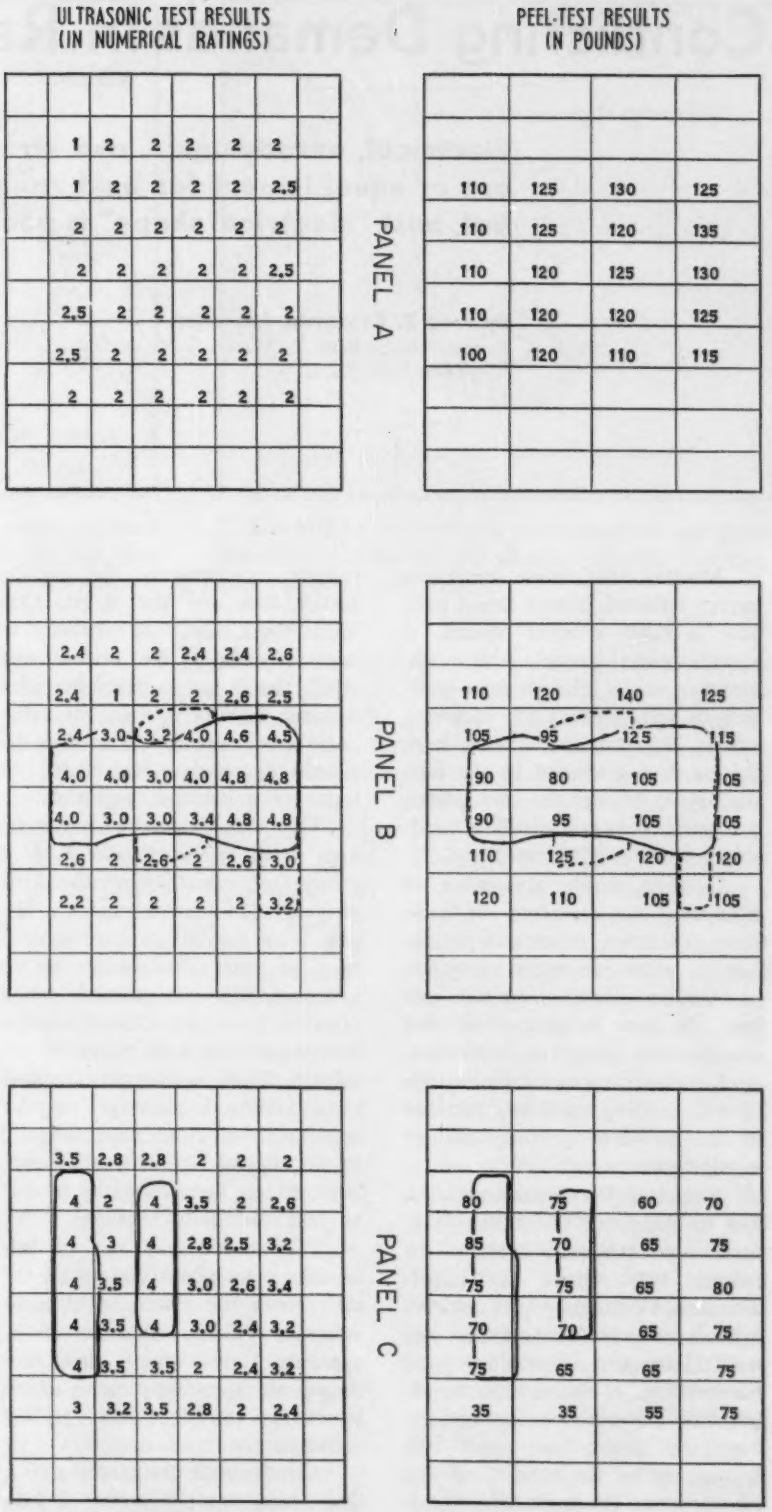


FIG. 7. COMPARATIVE VALUES are given as obtained from ultrasonic tests and peel tests. On panel "A", average peel-strength is 114 lb. In the unbonded areas of panel "B", as determined ultrasonically, peel strengths range from 80 to 105 lb; in the good areas the strengths are comparable to those of panel "A". Panel "C" has a low average of 77 lb.

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Conflicting Demands In Radome Design

Electrical, aerodynamic, and structural needs are of equal import for best range and accuracy, But, best "electrical shape" is poorest aerodynamically

By Fred R. Youngren, Manager
Aerodynamics Branch, Missile Systems Div.
Raytheon Co.

Missiles that home on radar energy reflected from a target must have a radar receiver aboard. A paraboloidal antenna or dish, mounted in the missile's nose is usually a vital part of the receiving system. To protect the dish from the air flow generated by the missile's flight through the atmosphere, a windshield is needed. This windshield is called a radome.

It must satisfy a number of conflicting requirements. It must have satisfactory electrical properties (to allow the radar energy to pass with minimum distortions and loss). It must be shaped so that aerodynamic drag is minimized. And, it must be structurally capable of withstanding the loads imposed by the air it is crashing through at supersonic speed.

Electrical Requirements — A loss in energy of the electro-magnetic waves passing through the radome will reduce the target-detection. Fortunately, it is not very difficult to obtain materials and wall thicknesses which allow good transmission. If the radome bends (refracts) the rays of energy coming from the target, the target will appear to be displaced from its true position. The angle of displacement is called the radome's boresight error angle (Fig. 1). This angle is usually less than 1 deg, but it changes in magnitude and sign depending on which region of the radome is between the missile seeker dish and the target. One might think that it is necessary to constantly keep the error angle small; this is not so, since the miss distance in feet due to the error angle is continuously reduced as the missile approaches the target. At intercept it becomes negligible.

The parameter which must be kept small is the angular rate of change of error angle over the radome. This requirement is imposed by the navigational system used to steer the missile to an intercept. The navigational system responds to apparent target angular movement rates with respect to the missile. Thus, a changing radome error adding to a target angular movement will either seem to speed up the angular rate or slow it down. Both effects can cause the missile to become wildly unstable.

The simple way out of this trouble is to mount and rotate the dish about the center of a hemispherical radome. Because of its symmetry, this shape does not change the apparent position of the target. It is too blunt, however, and generates too much drag.

Aerodynamic Requirements — The aerodynamicist prefers a long pointed shape for the nose of the missile (Fig. 2). This shape generates less drag because it turns the air through a smaller angle (the pressure increment on the nose tip is roughly proportional to the 3/2 power of the nose cone angle). To the aerodynamicist, weight is important; less weight means more range. This consideration would limit the radome length even if no other consideration were present, for as the radome grows longer, it also grows heavier. Eventually, the range decrement due to increasing weight balances the increment due to decreasing drag, and at this point the radome length gives maximum flight range. This occurs at a length-to-diameter ratio of from three to five. The exact ratio depends on the drag of the rest of the missile. Note that the electrical-

ELECTROMAGNETIC CHECKS on radomes for Sparrow III assure that radar beams are not defracted by surface irregularities or variations in thickness.

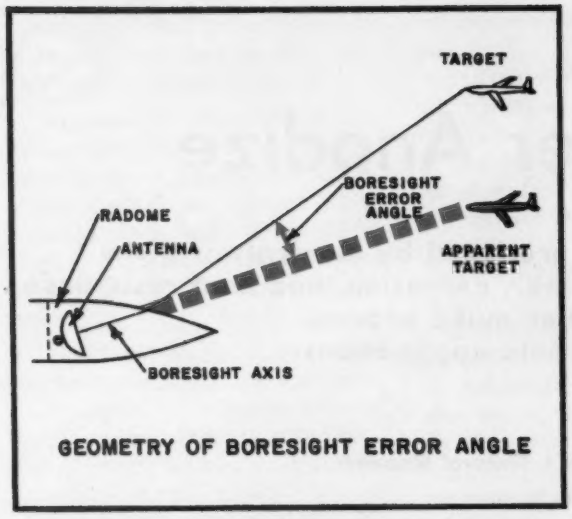

FIG. 1. ANGLE DISPLACEMENT is called radome's bore sight error angle. The angle is usually less than 1 deg. Effect is similar to looking at fish in water.

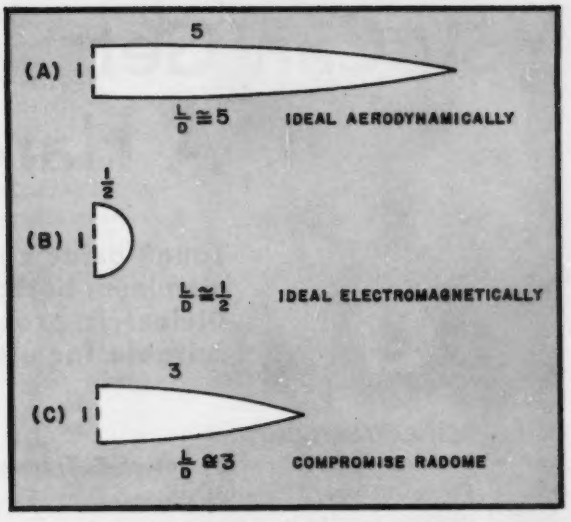

FIG. 2. IDEAL SHAPES for electromagnetic and aerodynamic requirements are almost opposite. Compromise shape is shown in (C).

ly optimum hemisphere has a length-to-diam ratio of ½.

Since the radome forms the contour of the missile nose, it is subjected to structural loading from the pressures of the air. This loading is of two types: a compression along the radome length due to the drag force; and, a bending load which occurs when the missile nose is inclined at an angle to the flight direction. The structure is usually a doubly-curved wall and for this reason compression is quite difficult to analyze. Because of geometry, however, the maximum bending moment occurs at the point where the radome joins the missile. Analysis is usually confined to checking the integrity of this joint.

Rain Erosion—A problem still not completely solved is the effect of rain erosion on radomes. Impact pressures of raindrops are high enough to fracture many materials, an effect which is further increased by surface imperfections. Only the hardest of metals and ceramics can escape damage from high speed rain impact. Experimental studies have shown that the erosion rate is proportional to a high power of the component of the impact velocity normal to the radome surface. For this reason, sharply pointed radomes with surfaces whose inclination to the airstream is small are preferred. Note that shapes whose aerodynamic drag is small tend to be of this type.

High speed flight also poses another radome design problem: aerodynamic heating.

Salt and Moisture — Salt encrustation on radomes used by the Navy is another problem facing the radome designer. This has the effect of increasing the wall thickness and thus detuning the radome from optimum electrical performance.

Moisture absorbed into the wall has a similar effect, in that it increases the dielectric constant of the material of the wall. This makes the wall appear to be electrically thicker and detunes the radome from optimum electrical performance.

Radome Materials — Most of the current missile radomes are fabricated of glass-reinforced plastics. This construction produces a tough, machinable, dimensionally stable material well suited for use as a radome. The chief restriction on its use comes from the limited ability of plastics to withstand high temperatures without deforming.

As missile flight-speeds increase, the need for materials with better properties than plastics at high temperatures has become more acute. The class of materials which can most immediately supply acceptable high temperature properties is the ceramics. They also have low electrical loss and resist rain erosion because of their hardness. This hardness, however, causes difficulties in machining. In order to overcome the forming difficulties, emphasis is being placed on molding directly to the final shape and thickness. A compromise, between the blunt nose desired by the electrical designer and the long pointed nose desired by the aerodynamicist, has been used in Sparrow III and Hawk.

Future Radomes—The future poses many challanges for the radome designer. Flight speeds are becoming so high that the air next to the radome is partially ionized. The high temperatures impose further problems on radome materials, both with regard to strength and to electrical properties. Some of the new breeds of missiles will be larger, increasing the problems of fabrication. The bending stresses in the radome wall are also increased for large radomes, because the wall thickness is designed to be tuned to the radar wavelength and therefore must be held constant.

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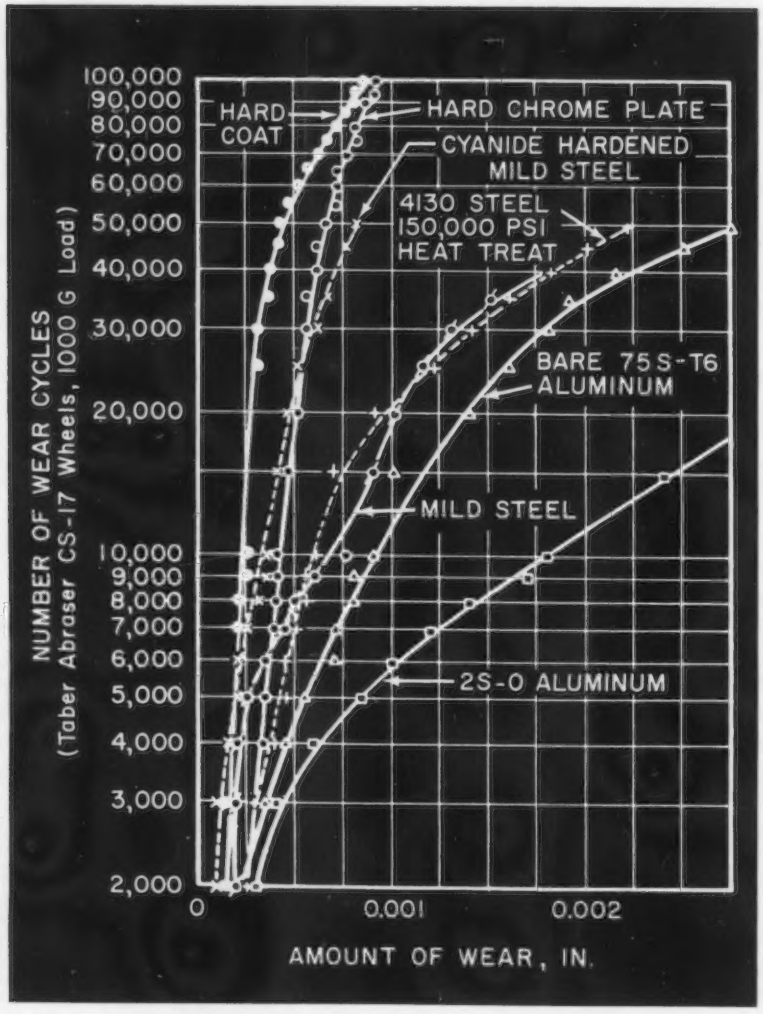
You Can Get A Harder Anodize

Tough oxide coat produced by electrolysis gives aluminum better wear, corrosion, and heat resistance. Dielectric properties make process suitable for electronic applications

by Joseph E. Trankla, Ass't. General Manager
Anachrome Corp., Div. Anadite, Inc.

WEAR-RESISTANCE OF HARD ANODIZING AS COMPARED WITH OTHER MATERIALS



Research into the anodic behavior of aluminum dates back some 100 years; modern anodizing practice is based on the Bengough-Stewart patent granted about 35 years ago.

Hard anodizing is a refinement of conventional anodic coatings formed by oxidizing aluminum surface in an electrolyte. Development of hard anodizing came about by recognizing the following needs: (1) development of oxide layer at a faster controlled rate; (2) high current densities; (3) colder electrolyte; (4) and other efficient heat dissipating methods.

Initially, insufficient knowledge and premature acceptance confined this process only to simple configurations, and to alloys of low-impurity content. Currently, complex shapes in all aluminum alloys may be hard anodized. Four recognized hard anodizing processes are now used: Alcoa, Martin, Hardas, and Sanford. Though all have a common aim, each may present an advantage of a specific nature.

General characteristics of hard anodizing vary somewhat depending on alloy, configuration and special requirements.

Nature of Film—Basically aluminum oxide with amorphous crystalline structure, the film is integrally bonded to the base metal. Film

color ranges from golden bronze to dark gray, depending on alloy, condition of metal, and thickness.

Application—Hard coatings can be applied to all wrought, sand-cast, investment-cast, and die-cast alloys. Some alloys, however, form oxide coatings more readily than others. This is because alloying constituents influence the structure of the coating.

Thickness — Although coating thicknesses of about 0.010 in. have been applied occasionally for salvage purposes, where alloy and configuration of part would allow, film efficiency drops rapidly beyond maximum optimum of 0.003 in. Thickness recommended for most applications is 0.002 to 0.003 in. also a flash coat of 0.0002 to 0.0005 in. may be applied to meet MIL-A-8625 requirements.

Dimensional Growth—Although the relation between growth and film thickness varies somewhat according to alloys, it can generally be stated that dimensional growth of about ½ the coating thickness will be encountered. A 0.002-in. coating will produce a 0.001-in. growth on surface, and should be so considered in design. Coating will tend to build perpendicular from base surface, hence, sharp edges should be eliminated when possible.

Uniformity in coating growth may be provided to within ± 10 per cent of coating thickness or better, when surface condition is consistent. Parts with non-uniform surface conditions, such as a machined surface and one as cast, create a problem; the machined surface will build more readily and uniformly than the as-cast surface. The somewhat passive surface of the as-cast area creates a semi maskant condition. This relative difference in ability to accept current density at the same moment, results in a hardcoat surface of different thickness and buildup between machined surface and as-cast area. This is used to advantage, for the resultant product will provide the required film thickness on all machined surfaces and the thinner but still corrosive-resistant coating on the as-cast surface.

A typical engineering callout on the drawing of a non-uniform surface part would be: "Hard anodize all over 0.002 ± 0.0002 in. on machined surface and sufficient coating to withstand 250 hr salt-spray requirement all over." To a lesser degree a variation of coating thickness will also develop on a part with machined surface and as-forged, or as-extruded surfaces.

Adherence — Film is strongly adherent to almost all alloys, especially those containing magnesium. It forms an integral part of the material and is an excellent base for paint.

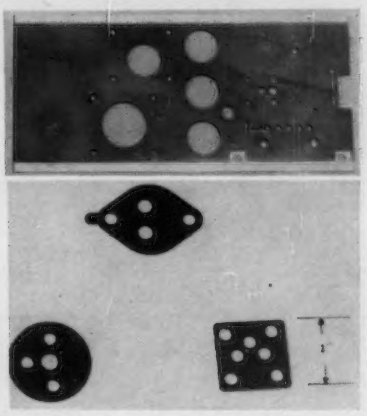
Surface—Roughness of surface is slightly increased by hard anodizing. Hard coatings provide an excellent process to eliminate seizure and present a good bearing or sliding surface. The surface layer may be honed, lapped, ground or polished to improve or change its quality. Extent to which a surface may be honed to a fine micro-finish depends greatly on alloy, manner in which part was formed, configuration of part and knowledge of processor. Surface may also be impregnated with any lubricating substance.

Coefficient of Friction — Tests definitely indicate that the hard coatings have a much lower coefficient of friction than the untreated metal.

Hardness — Accurate hardness values have not been determined by indentation methods, although the accepted values are Rockwell C45 to C65. The coating may be considered approximately file hard. A simple test of hard cost is to scratch with a curved die-sinker's file—#3 cut.

Ductility—The coating itself is extremely hard and therefore brittle. Under certain conditions it will crack after bending; it may even show a slight spall line on compression side after excessive bending but remains strongly bonded to base metal.

Fatigue Strength—Hard coating produces hardly any reduction in endurance strength on wrought alloys below stresses of 10,000 to 15,000 psi; at 25,000 to 50,000 psi a marked decrease is incurred. There is virtually no effect on endurance strength of cast alloys.



TRANSISTOR WASHERS and circuitry chassis are anodized by Anochrome Corp. using the Hardas process. Dielectric strength, thermoconductance, and ruggedness are advantages claimed.

Heat Resistance—Resistance of hard coatings to heat is excellent. The aluminum may be melted from under a hard anodize coating. On a Hardas coating, there is no evidence of change after heating to 500°C for 15 min.

Corrosion Resistance — Hard coatings are resistant to most of the common chemicals, but are attacked by strong acids and alkalies. Coatings have withstood more than 2000 hr salt spray. (Most specifications require 250-hr salt spray.

Electrical Conductivity — Hard anodizing acts as an insulator with a range breakdown from 400 to 3500 volts. (Practical design requirements call for less than 1000 volts.) Hardas process is being used quite extensively for parts such as: transistor washers, heat sinks, potentiometer mandrels, clips, etc.

Wear Resistance — On a wear scale, hard anodizing shows a superior wear resistance than Hard Chrome and steel. Hard anodizing against hard anodizing should not be used unless flowing lubricant is available to dissipate generated heat.

✦

Vectoring Reverse Thrust

Series of movable vanes made from welded tubing aid max thrust reversal on Convair 880

Thrust reversers on the Convair 880 use a series of vanes made from welded stainless and super alloy tubing to direct exhaust gases forward and reduce landing run-out distance. Factors which influenced the selection of these materials are:

- Ease of fabrication
- High strength and wear resistance
- Light weight of final component

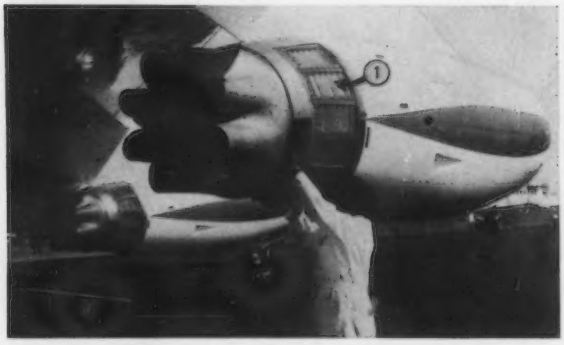
Major portion of the tubular vane is fabricated from 321 stainless steel. Short lengths of airfoil-shaped Haynes alloy No. 25 tubing are brazed to both ends of the stainless vane. These ends act as trunnions, or hinges, for positioning the vane. Haynes No. 25 is generally thought of as a high temperature metal, in this case it is used primarily for its excellent wear resistance.

The engine thrust is actually reversed by clamshell doors that close behind the engine proper, just forward of the sound suppressor. The reversed exhaust gases are then redirected by the series of the tubular vanes. They can be rotated to accurately control the forward component of thrust.

The airfoil shape of the vanes is formed in three separate operations by the Stalker Corp. from 1¾-in. OD. 0.028-in. wall tubing in 5½-in. lengths. The final forming operation uses a three-piece mandrel inserted in an enclosed die. Tolerance on the final forming is + 0.020 in.

The short trunnion pieces are formed from smaller tubing, ⅝ in. OD with an 0.063-in. wall thickness and a 1½ in. length. Its final forming tolerance is + 0.004 in. These shorter trunnion sections agree in contour with the mating portion of the airfoil shape of the larger vane section.

While controlling the directional force of the reversed thrust, the tubular vanes must have little effect on engine efficiency. Thrust reverser specifications set up by General Electric and Convair call for 5000 lb of reversed thrust. The same specifications require the thrust reverser activation time of no more than two seconds. Performance tests have produced thrusts of 5400 lb with activation time of less than one second and performance loss of less than one percent. ◆

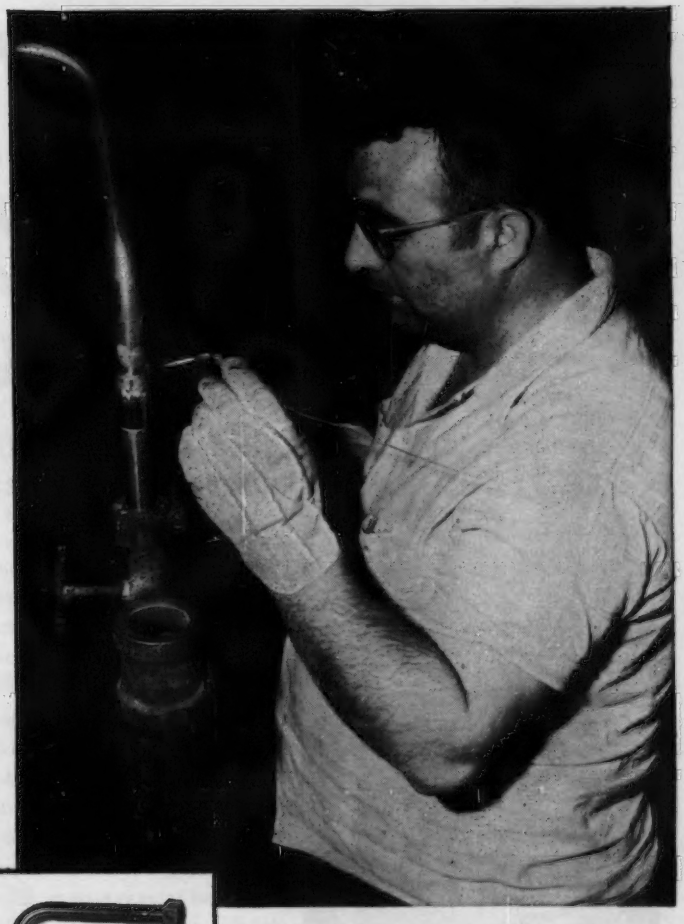


THRUST REVERSER on General Electric's CJ-805 can slow the 150,000-lb Convair 880 from 100 to 40 kts in 3000 ft without braking. Thrust is first reversed by clamshell doors (inside engine) then revectored by movable vanes (1).

HOLLOW VANES are made from welded tubing supplied by Standard Tube Co. Shorter trunnions of Haynes Alloy No. 25 are brazed to 321 stainless vanes. Airfoil is formed from 1¾-in. OD stock. Wall thickness is 0.028 in., length is 5½ in.

Titeflex, Inc., Meets Aircraft Fuel, Lubrication and Hydraulic Line Specifications with

HANDY & HARMAN BRAZE 541



Titeflex operator brazes assembly with torch and hand-fed Handy & Harman Alloy BRAZE 541. *Titeflex is unique in that it makes flexible hose assemblies from raw material to end product—"From End to End, Inside and Out, made RIGHT In Our Own Plant."*

This Springfield, Massachusetts, manufacturer of aircraft and missile fuel, lubrication and hydraulic lines finds that silver alloy brazing with Handy & Harman BRAZE 541 meets rigid operating requirements "all the way down the line."

The tubing and fittings of many of the wide range of assemblies made by Titeflex are 321, 316 and 347 stainless steel and Monel. Brazing is a hand torch, wire and HANDY FLUX operation.

BRAZE 541 is a plastic alloy which melts at 1325° F and flows at 1575° F. Its strength—in shear—at elevated temperatures is 21,500 psi at 500° F and 15,000 psi at 750° F. This alloy's ductility in resisting stress and vibration is very high and its resistance to oxidation and corrosion is equally impressive. The composition of BRAZE 541 is 54% silver, 40% copper, 5% zinc and 1% nickel. It meets AMS Specification 4772.

Aircraft and missile component manufacturers and fabricators are finding—to their and their products' benefit—that Handy & Harman silver alloy brazing is the full and *final* solution to their metal-joining problems. BRAZE 541 is but one of a large family of Handy & Harman alloys, for both low and high temperature applications. We would like to more fully acquaint you with BRAZE 541 and with the advantages that come naturally to silver brazing as a metal-joining (both ferrous and nonferrous) method. Handy & Harman, 82 Fulton Street, New York 38, N. Y.

FOR A GOOD START: BULLETIN 20

This informative booklet gives a good picture of silver brazing and its benefits... includes details on alloys, heating methods, joint design and production techniques. Write for your copy.

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Proved! New, Better Way to Seal Drilled Holes with . . .

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NEW PIN-PLUGS°

Seal simply, positively Prevent costly leaks!

Now — forget conventional, costly methods of sealing holes that serve as flow or pressure passages. The Lee "Pin Plug" is a cylindrical plug with a tapered reamed hole partway through its center and numerous small grooves on its outside surface. Simply place it into reamed hole and drive in the tapered pin until ends are flush. Controlled expansion causes grooves in plug to "bite" into casting and form independent seals and retaining rings. Extensive laboratory tests report no leaks under normal pressures, often show bone dry seals up to pressures of 40,000 psi.

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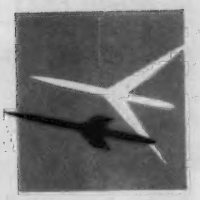
New Books

FUNDAMENTALS OF GUIDED MISSILES. By Air Training Command U. S. Air Force and Technical Staff Aero Publishers, Inc., Aero, 1959, 575 pp., $12.50. A thoroughly illustrated primer and reference book written in the direct style of a military manual. All fundamental aspects such as aerodynamics, propulsion, instrumentation, electronic control and guidance systems are covered together with explanations of physical principles involved. The first 4 pages consist of a useful glossary of guided missile terms and a short history of guided missiles.

GUIDE TO THE SPACE AGE. By C. W. Besserer and Hazel C. Besserer. Prentice-Hall, 1959, 320 pp., $7.95. This is a comprehensive work in dictionary form presenting in nontechnical language terms used in space technology and related sciences. It can serve as a reference volume to the general reader, as well as for the technicians actively engaged in these fields. Over 5000 standardized definitions are alphabetized and cross-referenced. Basic formulas, charts, graphs and abbreviations have been included for clarity; definitions are also given for many of the descriptive "space slang" terminology currently in use.

ADVANCES IN ASTRONAUTICAL SCIENCES. Proceedings of the Fifth Annual Meeting of the AAS, November, 1958. Plenum, 445 pp., $8.00. This volume, the fourth of a series giving a detailed picture of astronautical progress, includes papers on original technical research both from theoretical and experimental aspects. The papers presented are grouped under six categories: (1) Upper atmosphere research and re-entry mechanics; (2) Space vehicle design; (3) Guidance and instrumentation; (4) Satellite mechanics and space exploration; (5) Rockets and satellites; (6) Man's environment in space.



New Materials

Resists Gamma Rays

Estane, a flexible plastic, has been found to withstand gamma radiation better than any known conventional elastomer. Gamma radiation attacks long chain polymers in two ways: It chops them up and they become softer, stickier and weaker; or ties the chains together excessively and they become brittle. Estane molecules are not tied together by actual chemical bonds to begin with and thus can stand strong radiation doses before being converted into a non-usable condition. —B. F. Goodrich Chemical Co.

Circle 50 on postcard for more data

Plastic in Ceramic

Plaspreg resin can harden and strengthen blocks of low-density, fused quartz. Low-density fused quartz is outstanding in thermal insulation but is lacking in strength necessary to resist abrading and wearing stresses. Ability to accommodate fastening and attachment devices is also lacking. This resin can penetrate rapidly into the foam and, upon cure, offer a strong mechanical product. High temperature insulating qualities of the foam are retained.—Furane Plastics.

Circle 51 on postcard for more data

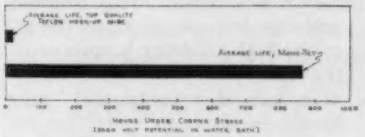
Foam Insulation

Polyurethane foam is designed to insulate any pipe from —300 to 275°F. Called Thermax it is constructed with a longitudinal seam which allows it to spread open to receive the pipe and, upon release, to snap quickly into the designated position. Due to its low K factor and longevity, Thermax is recommended for cold processing plants. Mobay Chemical Co.

Circle 52 on postcard for more data

Teflon Beats Corona

Failure under corona stress—the prime bugaboo of Teflon wire insulations may be a thing of the past. Corona resistance upwards of 70 times greater than the best Teflon-insulated hookup wire heretofore available is achieved with new CR Type coating. Improved proc-

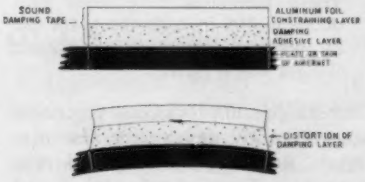


essing, which eliminates small voids at wire-to-coating interface, plays an important part in removing "breeding spots" for corona.—W. L. Gore Assoc., Inc.

Circle 53 on postcard for more data

Noise-Damping Tape

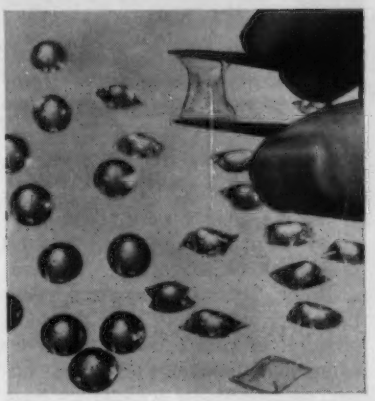
A pressure sensitive, visco-elastic tape is used to reduce noise inside the Convair 880. Applied directly to the interior skin of the



cabin, the damping material performs by converting mechanical energy to heat energy. When fuselage sections "vibrate" from external noise, the tape flexes and the visco-elastic layer attempts to move with the fuselage panel. But, an aluminum layer on the tape constrains it, and the vibration is absorbed as a shearing force in the visco-elastic as shown.—Minnesota Mining and Mfg. Co.

Circle 54 on postcard for more data

Glass Pillows



Low-cost glass pillows and balls are now being produced for filler, filter, packing, and tumbling applications. Lightweight hollow pillows (lower right), solid pillows, and ball-shaped pieces can be mass-produced in uniform shapes and sizes.—Corning Glass Works.

Circle 55 on postcard for more data

Beryllium Gyros

Beryllium gyros will be used in the guidance system for Titan. Beryllium in the housing and other parts of the gyroscope provides for a smaller package for the gyro assembly yet maintains good gyro characteristics. Reduced weight of the assembly allows for an increase of the mass of the gyro wheel. This increases the wheel's angular momentum, resulting in greater sensitivity.—AC Spark Plug.

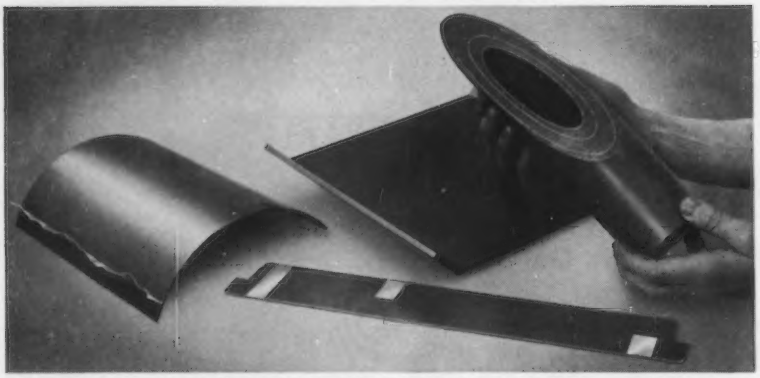
Circle 56 on postcard for more data

Molded Insulation

Resin-bonded molded fiberglass provides lightweight thermal insulation for an electronic chassis.—Fibrous Glass Products.

Circle 57 on postcard for more data

Important facts to know about laminated plastics



A few Taylor composite laminates (left to right): copper-clad section; sandwiched copper component; Taylorite vulcanized fibre-clad part; laminated tube, copper inserts.

Composite Laminates Open Up New Design Opportunities

While the great variety of commercially available laminated plastics satisfy most electrical and mechanical requirements, there are applications that can benefit from the combination of properties provided by composite laminates. Recent advances in bonding techniques have made it possible to bond virtually any compatible material with a laminate. These can be supplied as clad or as sandwiched materials. And they can be molded into many shapes to fit design requirements. Taylor is presently supplying to order the following composite laminates:

- **Copper and laminated plastics.** Clad for printed circuits and formed shapes. Sandwiched for special applications.
- **Taylorite® vulcanized fibre-clad laminates.** These combine the high strength of laminated plastics with the superior hot-arc-resistance of vulcanized fibre. They are being used in both high and low-voltage switchgear applications. Also in applications where the high impact strength of vulcanized fibre may be advantageous.
- **Rubber-clad laminates.** Almost any type of natural or synthetic rubber may be used as the cladding material. These laminates are widely used for condenser tops in wet condensers to protect the laminate against highly alkaline electrolytes. They also have application in any part where sealing or chemical resistance is needed.
- **Asbestos-clad laminates.** For applications where high heat- and arc-resistance are required.
- **Laminate-clad lead.** Lead sheets sandwiched between Grade XX paper-base laminates have been used for X-ray shields. The laminate provides strength and contributes to the high shielding properties of the lead.
- **Aluminum-clad laminates.** These have been used extensively for engraving stock. They also offer possibilities as printed-circuit material and as plate holders for X-ray machines.
- **Beryllium copper-clad laminates.** Beryllium copper is nonmagnetic and a good conductor—properties that give these laminates possibilities in many applications.
- **Stainless steel-clad laminates.** Applications where nonmagnetic properties are required. Also in certain corrosive environments where the resistance of stainless steel to attack is an asset.
- **Magnesium-clad laminates.** These laminates have been produced in 108-in.-long sheets for use as screens for X-ray operators. Weight was a factor.

Our design and production engineers are constantly developing new materials, new applications, and new procedures for fabricating laminated plastics. Our experience is yours for the asking. And if you have a problem requiring assistance or more information on composite laminates, write us. Also ask for your copy of Taylor's new guide to simplified selection of laminated plastics. Taylor Fibre Co., Norristown 50, Pa.

Taylor
LAMINATED PLASTICS VULCANIZED FIBRE

New Materials

Adhesive in Capsule

Packaging technique makes two-part epoxy adhesives simpler to mix and use in small quantities. Called PA Packettes the small plastic containers each hold a premetered quantity of both adhesive and catalyst. A typical assembly-line application for Packette adhesives is the

bonding of electronic components to circuit boards. The two components are colored in contrasting shades, typically yellow and blue. Workers are instructed to mix the components until a uniform color has been obtained. Bonded parts can be quickly inspected to see whether the adhesive and catalyst have been properly mixed.—Plastic Assoc.

Circle 58 on postcard for more data

Low-Temp Viton

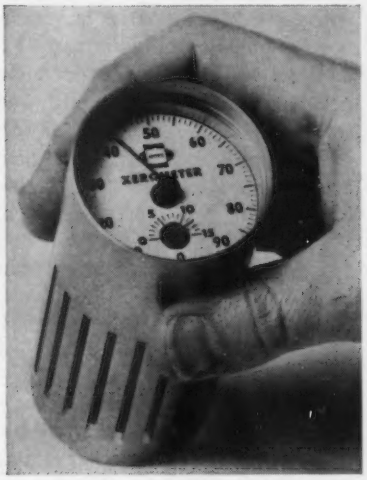
Viton (V500-6) retains flexibility at temperatures well below —100°F. Functional tests conducted by the compound developer indicate that it performs with excellent results in all hydraulic fluids and oils through the high temperature ranges generally associated with Vitons, —400 to 500°F.—Parker Seal Co.

Circle 59 on postcard for more data

New Parts and Components

Hygrometer

The Xerometer responds only to water. It reads relative moisture content over the full range of "bone



dry" to soaking wet; it functions reliably at extremely high or low temperatures, and is unaffected by most common solvents and other non-corrosive materials. The instrument provides a direct index of water in aircraft fuels, for insurance against freezing at low temperatures. Custom configurations are available for specialized applications. —Advinco.

Circle 60 on postcard for more data

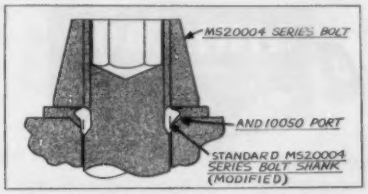
Teflon Hose

Fluoroflex-T high pressure hose assemblies are rated for 3000 psi from —67° to +400°F. These tetrafluoroethylene hose assemblies have an extended impulse test life of 250,000 cycles. They are furnished with specially designed swaged fittings to match characteristic of fitting to the properties of hose material. They are also lighter in weight than assemblies having screwed-together fittings. TFE inner tube is non-contaminating and non-aging.—Resistoflex Corp.

Circle 61 on postcard for more data

Bolt-Head Seal

Developed for installations where a removable plate must be attached to a high pressure vessel, thereby necessitating high strength bolts. Problem of sealing bolts such as the MS 20004 series was solved by designing the new seal with a heel wide enough to accept the bolt

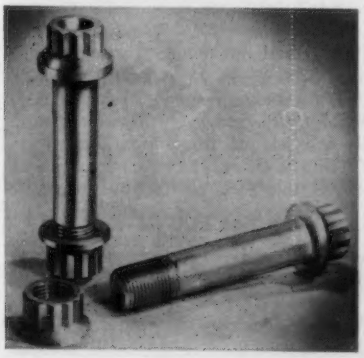


tension pre-load, and providing relief under bolt head and a chamfer around bolt hole. High pressure joints capable of holding pressures up to 10,000 psi from —400 to 1800°F have thus been obtained.—Harrison Manufacturing Co.

Circle 62 on postcard for more data

High Temp Fastener

Lightweight version of 900°F fastener consists of the LWB 922 bolt and companion FN 922 self-locking nut. These are for use with



high strength aluminum alloys, stainless steels and the superalloys. The threaded joint has 170,000 lb/in.^{2} tensile strength at 900°F and 220,000 psi minimum tensile at room temperature. Locking torque properties meet MIL-N-25027 requirements. Bolts and locknuts are available in all standard sizes from No. 10 through 1½ in. diam with fine threads. — Standard Pressed Steel Co.

Circle 63 on postcard for more data

Self-Sealing Coupling

The 3750 SAF-LOC self sealing coupling is for fuel, oil, low pressure hydraulic, pneumatic systems. Couplings connect and disconnect with a single, one-hand

movement. Positive thread action of nut gives a mechanical advantage that permits connection against line pressures up to 60 psi; will not disconnect accidentally under operational conditions up to 20 G's. Couplings have been fully tested in accordance with MIL-C-7413A.—Aeroquip Corp.

Circle 64 on postcard for more data

NEW AIRETOOL PNEUMATIC PRODUCTION TOOLS...

CUT COSTS AND STEP UP ASSEMBLY AND METAL FINISHING OPERATIONS

Model 400 GP

Model 400 GP General Purpose Sander and Grinder for fine metal finishing. Speeds metal sanding on both flat and contour surfaces. Light weight combined with hand comfort, pistol grip enables operator to work faster and longer with less fatigue. Permits salvage of large, used abrasive discs by trimming worn outer edges of 5, 7 and 9 inch to re-usable smaller discs.

Models 420 and 421 Automatic Push-Start Screwdrivers and Nutsetters. Ideal for fabrication and assembly of all plastic, wood and metal components. Positive-acting automatic push-start feature is actuated upon contact with work piece and quickly and securely seats either screw or nut. Fast, easy conversion from screwdriver to nutsetter accelerates on-the-job changeovers.

Models 420 and 421

Learn how the complete Airetool line of pneumatic production and maintenance tools can help you increase production while cutting costs. Contact your nearest representative or write today for free descriptive catalog.

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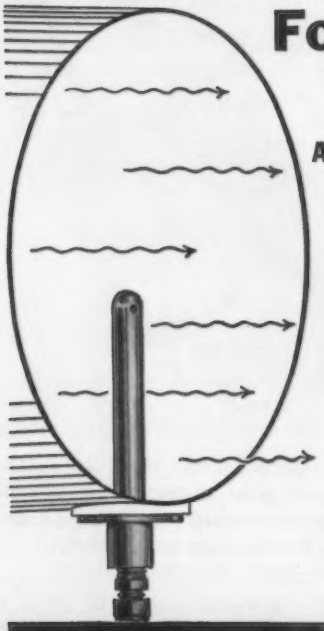
AIRETOOL MANUFACTURING COMPANY SPRINGFIELD OHIO

Circle 21 on Inquiry Card

Non-Cooled Thermocouple For High Velocity Gas Streams



At Temperatures Up To 3600°F.

This new thermocouple can be used without water or air cooling in the high velocity gas streams of jet engine afterburners and ramjet and rocket exhausts. It includes a cermet radiation shield and support tube. Conduction errors from cooling are eliminated and installation is simplified. Radiation losses are reduced about 60%. In a typical application this probe endured temperature cycling from 1500 to 3000°F. at a 1500 ft./sec. velocity for 20 hours with no failure. Temperature changes of 2000°F./sec. have created no adverse effects. Conductors used are Platinum 30% Rhodium/Platinum 6% Rhodium to 3000°F., and Iridium Rhodium/Iridium to 3600°F. Contact Thermo Electric for adaptation of this thermocouple to your needs.

Write For EDS-36-1

Thermo Electric CO., INC.
SADDLE BROOK, NEW JERSEY

In Canada:
THERMO ELECTRIC (Canada) LTD.,
Brampton, Ont.

New Parts and Components

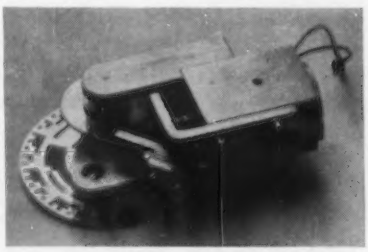
Flexible Tubing

Available in stainless steel or aluminum, it may be used for heater lines, air ducts and electric wire conduit. Aluminum tubing is 32 gage in 0.010 to 0.012 in. thickness. Stainless tubing types 302, 321 and 430 are available in thicknesses from 0.010 to 0.012 and from 0.017 to 0.020 in. Both versions are made from interlocked continuous strip metal. Available in following OD sizes: 1⅛, 1⅜, 1⅝, 1⅞, 2⅛, 2⅜, 2⅝, 2⅞ and 3⅛ in.—The International Metal Hose Co.

Circle 65 on postcard for more data

Sequence Programmer

Miniature solenoid-actuated switching device encodes or decodes events in a sequence. Operates with solid-state circuitry over a wide range of input rates; employs an interchangeable coded disc to sense the sequence of events. Precise indexing action permits division of the program disc for sequences requiring up to 100 switch positions. Device is less than 1¾ in. long and weighs 0.9 oz. It is rated for 4 to 8 volts and will operate with input pulses as short as 11 milliseconds up to 70 indexing motions per second. Operates in —40° to 165°F environment.—Elgin National Watch Co.

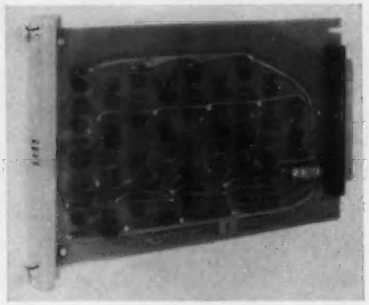


Circle 66 on postcard for more data

New Electronic Products

Solid-state Modules

Solid-state modules—"building blocks" of printed circuitry make it possible to build digital systems to any size for the acquisition and processing of test data. With the



modules digital systems can be assembled to multiplex and digitize data at rates up to 15,000 samples/sec with an accuracy of 0.05 per cent. Thirty-seven modules make up a basic "library" of digital components.—Minneapolis Honeywell Regulator Co.

Circle 67 on postcard for more data

Transistorized Recorders

Standard recorders can be equipped with either one or two set points for maximum-minimum control. This feature was previously available only on potentiometric recorders or separately on controllers. There is no interference with the writing pen. The "maximum set point" can be fixed in any position over a range of 30 to 100 per cent of full scale and the "minimum set point" can be used between 0 to 70 per cent full scale. Accuracy varies between 0.5 per cent at the center of the scale and 3.0 per cent at the end of the scale.—Curtiss-Wright Corp.

Circle 68 on postcard for more data

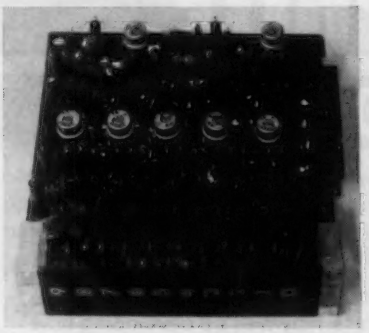
Electronic Ruby-Ear

"Electronic ear," considered one of the most sensitive listening devices invented to date, can pick up faint radio signals from interplanetary rockets. The super-detector, a 25-lb "ruby maser," could extend by tenfold the sensitivity and range of many electronic systems. Earlier masers at best were bulky and complicated. They required a large vacuum pump and a magnet weighing up to 500 lb and costing more than $4000. The new maser does the same job with no pump and a 12-oz magnet that costs $10.—Hughes.

Circle 69 on postcard for more data

Decade Counter

A transistorized 100 KC Add-Subtract decade counter features simple switching control. Grounding one of two control lines determines whether decade will add or subtract. Available in single voltage

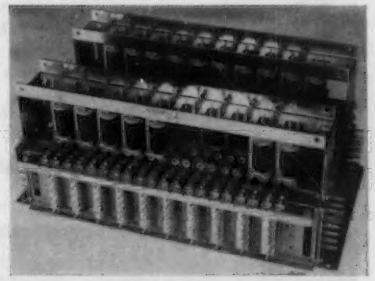


model 1303 requiring +100 V @ 40 Ma.; or lower dual voltage model 1203 requiring +30 V @ 35 Ma., and 60 V AC @ 1 Ma. Bright, ten number display, electrical zero reset, and optional coincidence output. Plugs into standard 10-pin PC connector. Size: 3 9/16 x 1 x 3¾ in. Weight 3 oz.—Robotomics, Inc.

Circle 70 on postcard for more data

Crossbar Switch

Versatile, high frequency crossbar switch requires only limited space and eliminates bus wiring. It is particularly suitable for video, audio and sync switching, and has



specific application for radar, sonar and low level signal distribution. The basic unit measures only 4-3 x 12¼ x 2⅝ in. and weighs 4½ lb. It can switch sequentially or at random up to 120 circuits. The Type P switch terminals accept AMP 78 taper tab connectors, a connector plug or can be soldered to meet varying customer requirements. — James Cunningham Son & Co., Inc.

Circle 71 on postcard for more data

Shock Indicator

Mounted with sensitive equipment in a shipping container, Shock Overload Indicator shows any excessive shock that may occur in transit. A spring-loaded mass is tripped and bares a red color spot behind a clear plastic cover. The unit is sensitive to acceleration in one direction in the longitudinal axis and in all transverse directions. The sensitivity in the longitudinal and transverse directions can be made different. Two units mounted back-to-back provide full spherical sensitivity.—Convair Instruments.

Circle 72 on postcard for more data

NOW in 50 WATTS for MINIATURE and SUBMINIATURE PRODUCTION SOLDERING JOBS

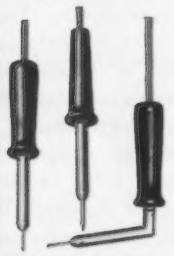
the NEW, American Beauty BANTAM "X" series

Designed with 50 watt input, these fine soldering irons will give greater productivity and do industry's most exacting soldering jobs easier, faster, better. SLOTTED STAINLESS STEEL CASINGS MAKE THE HANDLES REALLY COOL, ending operator complaints. There's no waiting or fumbling with these light, flexible tools — they're always ready. American Beauty soldering irons are known the world over for their dependability, durability and efficiency. Learn more about these fine soldering tools today.

YOU CAN'T BEAT A SOLDERED CONNECTION

WRITE FOR DESCRIPTIVE CATALOG SHEET, FORM NO. 222-CT

Shown below are other shapes and tip-size irons available in the BANTAM "X" series.



AMERICAN ELECTRICAL HEATER COMPANY

DETROIT 2, MICHIGAN

Circle 23 on Inquiry Card

WHAT MORE DO YOU WANT GRAPHITE TO DO FOR YOU?

Graphite has been useful in aircraft and missile problem-solving as a component material in rocket motors, in brazing fixtures for airframe construction, and in other refractory applications.

Further and more advanced uses of graphite in space age progress may well be developing now as part of your design engineering program.

As one of the world's largest producers of high quality graphite, we would welcome having our engineers and technicians work with you on these developments.

May we have the pleasure of hearing from you?

PRODUCTS YOU CAN TRUST — GLC — ELECTRODE DIVISION

GREAT LAKES CARBON CORPORATION

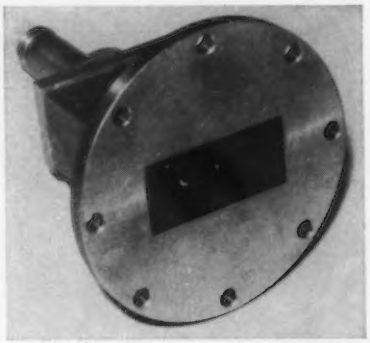
18 EAST 48TH STREET, NEW YORK 17, N.Y. OFFICES IN PRINCIPAL CITIES

Circle 24 on Inquiry Card

New Electronic Products

Waveguide Adapter

In-line adapter from type N coaxial connector to UG-149A/U waveguide flange facilitates microwave packaging. VSWR is less than



1.25 from 4400 to 6000 MC. Detailed VSWR and loss curves, as well as an outline drawing, is available on request.—Radar Design Corp.

Circle 73 on postcard for more data

Drift Angle Indicator

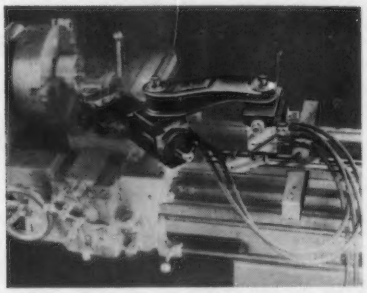
Ground speed and drift angle indicator is constructed in accordance with ARINC characteristic #540 and is specifically designed to be utilized in commercial transport aircraft. Ground speed information is provided on a 3-drum counter by means of a follow-up servo, and drift angle is displayed on a calibrated dial by means of an electrical signal from an 11 synchro transmitter. The instrument is integrally illuminated according to MIL-L-25467A. It contains a transistorized, repairable servo amplifier and a DC power supply.—Kearfott Div. of General Precision.

Circle 74 on postcard for more data

New for Production

Tracing Attachment

New tracing attachment for lathes is quickly installed and removed. The MARK II unit, pivot-



type design, is suitable for both shaft and facing duplication. System is entirely hydraulic.—True-Trace Corp.

Circle 75 on postcard for more data

Tests Components

Temperature chamber is designed for missile/aircraft components tests. It provides high/low temperature environments in conjunction with vibration in all three axes.

Optional hydraulic lift makes the TE-100 self-elevating for use over vibration exciters or oil-film vibration slip tables. Chambers may be ordered in sizes to fit any specimen.—Wyle Manufacturing Corp.

Circle 76 on postcard for more data

Measures Liquid H_2

Miniature platinum resistance thermometer gives rapid temperature measurements of liquid hydrogen. This Type 2660 stainless steel transducer incorporates a trimming network which permits both accuracy and interchangeability to be maintained to ±0.1°F over the –435F to –400F range.

Since the platinum sensing element comes in direct contact with the liquid hydrogen, a thermal time constant of less than 200 milliseconds is realized. A perforated shield, 0.160-inch diameter by 2¼ in. long, protects the winding from mechanical damage and permits the unit to operate in liquid flows as high as 60 ft per second.—Transonics Inc.

Circle 77 on postcard for more data

Electron Beam Vacuum Furnace

Electron beam furnace can melt, alloy, and refine ingots of up to 50 lb in tantalum. It acts similarly on proportionate weights of other reactive and refractory metals including molybdenum, columbium, tungsten, thorium, cobalt nickel and hafnium.

Previously, contamination from electrodes or from crucibles often added impurities that changed the properties of such metals.

This new bombardment - type vacuum furnace, designated Model 2460, will produce ingots up to 4 in. in diam and 14 in. long. Furnace is divided into two separate chambers. One contains the electron gun. The other holds the mold and metal feeding mechanism. Each has its own pumping system. —NRC Equipment Corp.

Circle 78 on postcard for more data

Epoxy Base Ink

Permanent marking ink eliminates smeared stencil information, resists effects of cleaning solutions.

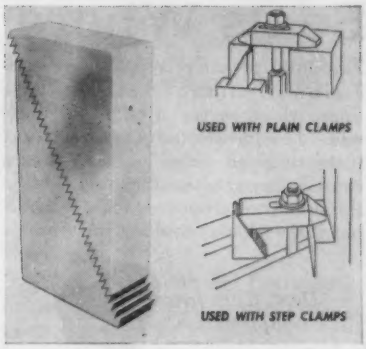
Markings are color stable on surfaces exposed to temperatures up to 260 deg F for the white ink and 350 deg F for the black.—Melpar Inc.

Circle 79 on postcard for more data

Step Blocks

Aluminum step blocks are used with either plain or step clamps.

Nine sizes are available; three

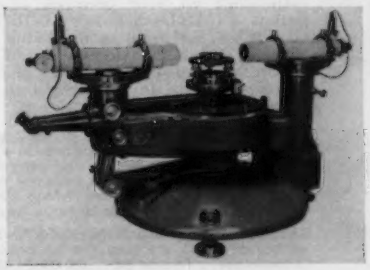


sizes of standard blocks 1 in. wide, three sizes of heavy duty blocks 1½ in. wide, and three sizes of double duty blocks 2 in. wide. Blocks are interchangeable.—Northwestern Tools Inc.

Circle 80 on postcard for more data

Goniometer

Microptic precision goniometer calibrates divided circles, polygons and angle gages. Direct reading is to .1 second of arc. Bearing for the



worktable carries a glass divided circle. Autocollimating telescope unit also contains an optical system for determining the mean value of the opposite side circle readings. —Engis Equipment Co.

Circle 81 on postcard for more data

SILICONE NEWS from Dow Corning

Photo courtesy Fairchild Engine & Airplane Corporation

Seals Where Others Failed

Fairchild recently supplied several F-27B's to Northern Consolidated Airlines, which serves Alaska and Canada. Trouble started when temperatures dropped below —50 F. Seals caused doors to stick closed. After the doors were opened, seals were so hard the doors couldn't be closed. Silastic®, the Dow Corning silicone rubber, was used to replace the seals for the large cargo and passenger doors. Results: no sticking closed, no jamming open . . . Silastic maintains a positive seal at all altitudes despite the wide variations in temperatures encountered.

Write to Dept. 0306 for information

first in silicones

Dow Corning CORPORATION
MIDLAND, MICHIGAN

Circle 25 on Inquiry Card

THIS COUPON WILL BRING YOU A VALUABLE BOOKLET ON TESTING WITH CARDOX CO_2. SEE OFFER BELOW.

Get the facts on CO_2 Testing

CARDOX®

PIONEERS OF CO_2 FOR ENVIRONMENTAL TESTING

-100°F. IN SECONDS WITH ABSOLUTE CONTROL—yours with a Cardox Bulk Liquid CO_2 Storage Unit installed, serviced and maintained on your premises. Exclusive, patented CARDOX CO_2 VAPOR RECYCLE SYSTEM insures maximum cooling effect of carbon dioxide at point of use—at all times. Cardox carbonic gas and dry ice also available in any quantity to suit your specific testing needs.

MAIL THIS COUPON, attached to your signed letterhead, to Cardox. You will receive your copy of a new, illustrated booklet which fully describes the various methods of testing with CO_2 in use today, and shows how Cardox CO_2 Vapor Recycle System can bring new economy, efficiency and reliability to your operation. Send for your copy today.

CARDOX PRODUCTS: Carbon Dioxide Fire Extinguishing Systems, Trucks, and Foam Fire Equipment . . . Liquid Carbon Dioxide . . . Carbonic Gas . . . Dry Ice.

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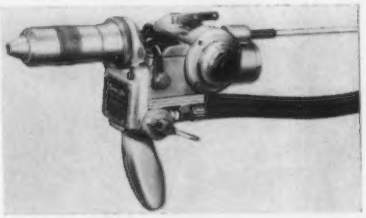
Regional offices: Jersey City, N. J., 7th & Provost Sts.; Memphis, Tenn., 784 Mississippi St.; Detroit, Mich., 1723 W. Lafayette Blvd.; Chicago 9, Illinois, 43rd & Marshfield; Fort Worth, Texas, 825 N. Calhoun St.; Los Angeles, Cal., 151 North Avenue 19

Circle 26 on Inquiry Card

New for Production

Spray-gun

Spray-gun applies protective coatings to base materials. It permits use of rods up to ¼ in. diam. Gun automatically heats and melts



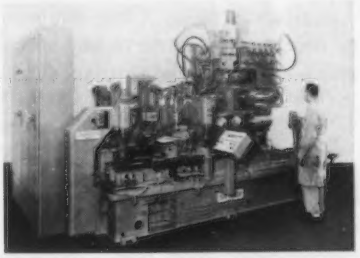
a rod of the protective material, mixes it properly with oxygen, and then sprays it on the surface to be protected. Auxiliary air supply gives additional pressure at the nozzle, attaining more angles of projection. —Metallizing Co. of America.

Circle 82 on postcard for more data

Mills Missile Wings

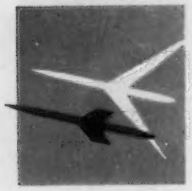
Programmed tool performs milling, drilling and tapping operations on cast aluminum alloy missile wings at a rate of 17 pieces per hour at 100 per cent efficiency.

Missile wing is clamped in a fixture and traversed on hardened and



ground ways to various machining positions. In completing the machining of the part, work fixture is moved by a hydraulic cylinder arrangement along a 68-in.-long path. —Snyder Corp.

Circle 83 on postcard for more data



Worth Asking For

Fuel Cells

Booklet discusses basic facts about fuel cells.—*General Electric Co.*

Circle 84 on postcard for more data

Socket Screws

Technical reference, 82 pages, on industrial socket screws. — *Standard Pressed Steel Co.*

Circle 85 on postcard for more data

Drills

Circular on deep hole drills. — *Pratt & Whitney Co.*

Circle 86 on postcard for more data

R D C A

Brief outline of new firm's purpose.—*Resources Development Corp. of America.*

Circle 87 on postcard for more data

Reprints

Two reports available, "Machining of Cobalt — Containing Alloys" and "Permanent Magnets at High Temperatures" — *Cobalt Information Center.*

Circle 88 on postcard for more data

Transistor Guide

Transistor application guide. — *Lansdale Div., Philco Corp.*

Circle 89 on postcard for more data

Laminated Plastics

Laminated plastics selection guide combines a 12-page manual with a quick-reference chart of characteristics for 21 commonly-used laminate grades.—*Taylor Fibre Co.*

Circle 90 on postcard for more data

Synchro Catalog

Catalog contains definitions of synchro parameters, dimensional drawings, characteristics of basic line synchros. — *John Oster Manufacturing Co.*

Circle 91 on postcard for more data

Polaris Guidance

Brochure pictures Navy's 60,000 sq. ft. Polaris inertial guidance equipment facility at Pittsfield.—*Ordnance Dept. General Electric Co.*

Circle 92 on postcard for more data

Addresses

"Engineering's Great Challenge—The 1960's"—Three addresses by Hilliard W. Paige. — *MSVD, General Electric Co.*

Circle 93 on postcard for more data

Datex

Facilities brochure.—*Datex Corp.*

Circle 94 on postcard for more data

Ferrous Metallurgy

Basic Guide to Ferrous Metallurgy: Multicolored chart shows and defines transformation and working ranges ferrous metals from —300 to 2900°F.—*Tempil° Corp.*

Circle 95 on postcard for more data

Span

April issue of SPAN, firm's monthly, includes data on tunnel diodes, solar cells uses in Explorer VI. —*Hoffman Electronics Corp.*

Circle 96 on postcard for more data

Hi-temp Testing

Catalog 70 on "elevated temperature test equipment."—*Research Inc.*

Circle 97 on postcard for more data

Contamination Control

Handbook on contamination control for liquid propellant rocket engines. Available only to qualified personnel in engine components or complete systems.—*Aerospace Industries Asso.*

Circle 98 on postcard for more data

Refractory Brick

Booklet shows facilities, steps in brick manufacture.—*General Refractories Co.*

Circle 99 on postcard for more data

Ceramics

Alumina uses described.—*Aluminum Co. of America.*

Circle 100 on postcard for more data

Fiberfrax

New ceramic fiber described; showing insulation used in Project Mercury.—*The Carborundum Co.*

Circle 101 on postcard for more data

Variable Transformers

Design drawings of "Powerstat" transformers for high frequency use. —*The Superior Electric Co.*

Circle 102 on postcard for more data

High Alloy Casting

Article on factors involved in selecting high alloy heat resistant castings withstanding 1200°F. — *Alloy Casting Institute.*

Circle 103 on postcard for more data

Drafting Aids

Reference chart on printed circuit drafting aids.—*By-Buk Co.*

Circle 104 on postcard for more data

United

New firm's aims, capabilities. — *United Industrial Corp.*

Circle 105 on postcard for more data

Explosive Forming

Bulletin on the Explosi-form process for shaping metal parts by means of explosive energy.—*Propellex Chemical Div.*

Circle 106 on postcard for more data

Solid State Conversions

State-of-the-Art advancements on new systems and components graphically presented in brochure. — *Cook Electric Co.*

Circle 107 on postcard for more data

Oil Chart

Oil chart for selecting proper grade of cutting lubricant for various materials. — *The Eastern Machine Screw Corp.*

Circle 108 on postcard for more data

Instruments

Catalog of electronic instruments for measurement and control, r & d, environmental testing.—*Acton Laboratories.*

Circle 109 on postcard for more data

Wind Tunnel System

Bulletin shows how NASA reduces high-speed wind tunnel data at Langly Field.—*Systems Div., Beckman Instruments.*

Circle 110 on postcard for more data

Insulating Resins

Easy-to-read guide to insulating resins and their uses. — *Marblette Corp.*

Circle 111 on postcard for more data

Temp Controls

Temperature control packages for industrial processes.—*Assembly Products, Inc.*

Circle 112 on postcard for more data

Balloons

Folder on firm producing Project Echo reflective balloon. — *Schjeldahl Co.*

Circle 113 on postcard for more data

Guidance Tests

24 page brochure on Inertial Guidance Test Equipment And Components.—*Sterling Precision Corp.*

Circle 114 on postcard for more data

Silicone

Silicone reference guide. — *Dow Corning Corp.*

Circle 115 on postcard for more data

Lathe

Brochure gives complete description of Powerturn 45 deg. Copymatic lathe.—*Lodge & Shipley.*

Circle 116 on postcard for more data

Men on the Move

Richard M. Hultberg
Radiation Inc.

Douglas V. Dorman
Martin

Dimitrius Gerdan
Allison Div.

G. W. Hatzenbuhler
Norden Div.

Dr. Milo P. Hnilicka
National Research

Dr. Richard W. Eppley
Norair Div.

Iden F. Richardson
Hughes Aircraft

Robert M. DeHaven
Hughes Aircraft

RICHARD M. HULTBERG, appointed director of the Systems Development Div., Radiation Inc.

COURTLAND DAVIS PERKINS, is the new Assistant Secretary of the Air Force for Research and Development.

DOUGLAS V. DORMAN, named corporate vice president of industrial relations for The Martin Co.

DIMITRIUS GERDAN, appointed manager; JAMES E. KNOTT, named director of engineering at the Allison Aircraft Engines Operations, General Motors.

JACK BRINER, named director of quality assurance and field service; MILTON L. STRATTON, appointed chief inspector of supplier products; WILLIAM GAHAN, made field service manager; at AC Spark Plug, Div. of General Motors.

GEORGE W. HATZENBUHLER, has joined United Aircraft Corp. Norden division as purchasing agent for the Norden Laboratories and Milford departments.

DR. MILO P. HNILICKA, promoted scientific assistant to the vice president and director of research for National Research Corp.

DR. RICHARD W. EPPLEY, has joined the Astro Systems and Research Laboratories of Northrop's Norair Div.

ROBERT B. STAUFFER, appointed training director for the Mishawaka Div. of the Bendix Corp.

T. N. DUNCAN, appointed manufacturing manager of the Aero Hydraulics Div., Vickers Inc.

IDEN F. RICHARDSON, appointed a vice president of Hughes Aircraft; DR. R. L. RODERICK, named manager of ballistic missile and ballistic missile defense systems; J. W. LUDWIG, manager of space systems; LEONARD MAUTNER, special systems; R. K. AUSBOURNE, tactical missile systems; and DR. L. J. MONEY, tactical aircraft systems; ROBERT M. DEHAVEN, appointed manager of the flight test div. DR. MARVIN FOX has joined the nuclear electronics lab as senior staff physicist.

PAUL JONES, JR., has joined Horkey-Moore Associates as manager, customer relations.

JOHN A. MORENO, appointed executive assistant in charge of engineering administration at the Pomona Div., The Marquardt Corp.

C. L. HEWITT, appointed manager of sales in the Missile Systems Div., Republic Aviation Corp.

STANLEY M. SMOLENSKY, appointed executive director of marketing at the Reaction Motors Div., Thiokol Chemical Corp.

EDMUND VAN CLAXTON, appointed T58 engine project manager at General Electric's Small Aircraft Engine Dept. DR. DAVID L. DOUGLAS, named manager of fuel cell engineering at the Aircraft Accessory Turbine Dept.

R. A. IRWIN, appointed director of space activities for the Westinghouse Electric Corp.

MARTIN B. BLOCH, named chief engineer at the Electronics Div., Bulova Watch Co.

JOHN AGNITCH, has joined the marketing staff of Space Technology Operations at Aeronutronic, Div. of Ford Motor Co.

DR. THOMAS T. OMORI, appointed European Manager of the NATO-Aerojet Propulsion Program for the production of motors for the HAWK missile.

ROBERT A. WAGNER, appointed manager of the helicopter engineering department of Hughes Tool Company's Aircraft Division.

JOSEPH BREN, has joined REF Manufacturing Corp. as a project engineer in the company's newly formed Ground Support Equipment Section.

Industry Notes

Tiros Fabrication

Cylindrical structure carrying all active components of Tiros weather-satellite is a precision fabrication job of Lavelle Aircraft Corp., Newtown, Pa.

Structure is shaped like a drum, with 42 in. diam, and 22½ in. depth. Its top and sides are covered with more than 9000 solar cells which generate electricity directly from sunlight to charge storage batteries used to power internal electronic equipment.

Satellite is made of aluminum alloy formed sheet and extrusions rivated together. Base plate and top plate, reinforced with radial and circular ribs, are joined together by extruded aluminum alloy T sections, which serve as a frame for the 18 removable side panels.

Top plate and the 18 panels on which the solar cells are mounted are flat, to provide the proper surface for the cells. To meet various operational requirements, some of the detail parts were finished by a hard coat anodic process, while others were black anodized.

Active satellite components, which include television cameras, video tape recorders, transmitters, power sources, and complex control and communications equipment, are carried on the base plate.

The 900 silicon solar cells were manufactured by International Rectifier Corp., El Segundo, Calif.

Tiros system was designed and built by RCA's Astro-Electronic Products Div., Princeton, N. J.

Zero gravity will be simulated for long periods in "null gravity simulator" at Lockheed's Georgia Div. Research subjects are inside revolving tank of water.

Titan Guidance-Reference

Details of the guidance reference system used in the first two minutes of flight in recent Titan shots:

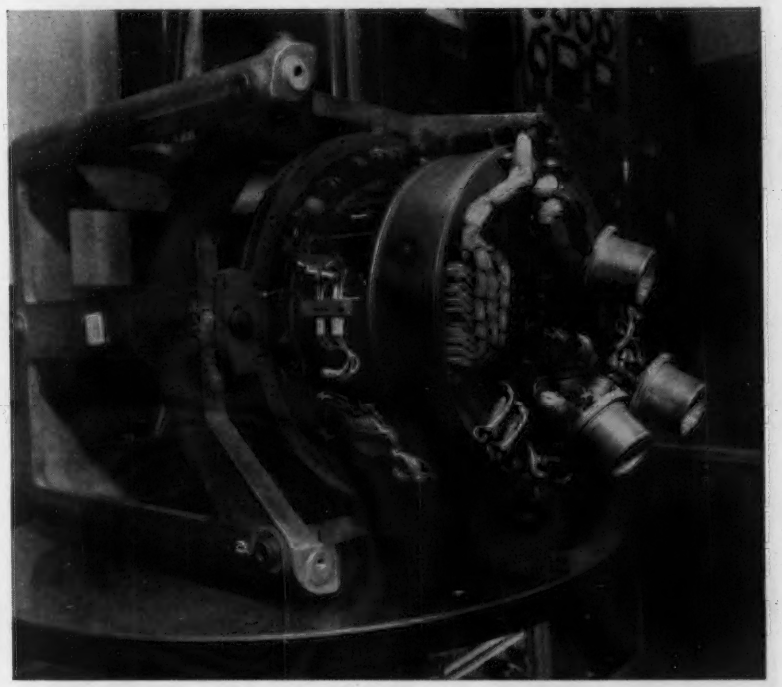
Guidance system, developed by Aeronautical Div., Minneapolis Honeywell Regulator Co. under contract to Martin-Denver, is an advanced version of the "strapdown" concept. This fastens gyroscopes rigidly to the frame of the missile. Gyros react according to pre-set time signals and external guidance commands.

Components: three hermetically-sealed integrating gyroscopes, a missile attitude programmer and an electronically controlled timer. Function of the system is to provide roll-and-pitch programming and three-axis reference for the guidance and control of the missile.

The system supplies command signals to the autopilot to guide the missile on a pre-chosen path from the time of launch until the missile's radio guidance system takes over.

When the Titan's 80,000-pound-thrust second stage fires in space, a guidance system directs it to the start of its ballistic trajectory. During this second-stage flight, the reference system senses deviations in the Titan's attitude and provides corrective signals to the control system.

The system is cylindrical—approximately 12 inches in diameter and 15 inches high. It weighs 45 lb. Entire package is transistorized and designed to withstand rugged environmental requirements.



TITAN GUIDANCE uses "strapdown" concept.

Industry Notes

How SECOR Works

SECOR system to be used in Transit IB preliminary satellite-mapping, works this way:

System measures spatial coordinates of a satellite as a function of time. For geodetic work, it employs minimum of three ground-based DME (Distance-Measuring Equipment) stations separated by 1000 or more miles. A fourth station is the unknown point which is to be surveyed.

Position of fourth station is found by measuring its range to satellite at several known points in satellite's orbit.

Secor, which stands for SEquential COllation of Range, uses a frequency-modulated, continuous-wave signal transmitted from ground to 6½ lb transponder in satellite,. Transponder repeats signal on an offset carrier frequency, allowing ground station to determine distance by measuring phase shift.

System determines satellite ephemeris on a single pass. Prime contractor for the Army is Cubic Corp. Future uses may include vehicular rendezvous in outer space, guidance and stabilization of a 24-hour satellite and variation of satellite orbit inclination.

SECOR specifications include 10,000 mi range, frequency of 482-512 mc, sequencing of 40 cps. transmitting power of 500 watts.

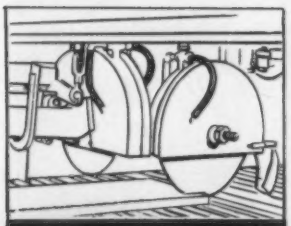
Considered part of the "Project Betty" operation, which has three MINITRACK MARK II stations on Pacific Ocean Islands taking observations on the Navy VANGUARD satellite since 1958, the new system is better suited than MINITRACK to the Army Map Service accomplishment of its geodetic mission. It will measure distances representing the sides of triangles extending from the earth stations to the TRANSIT borne instrument instead of the measurement of space angles under the present system.

Use of the new distance measuring equipment will give geodetic position locations to at least one order of magnitude more accurately than can be expected from MINITRACK MARK II. Position locations obtained by MINITRACK MARK II data have been estimated to be accurate within about 300 meters. SECOR is expected to reduce this margin to about 30 meters.

The new system is expected to provide better data for determining geodetic quantities such as the figure of the earth, intercontinental ties and location of small, isolated islands to a common reference system. Another anticipated geodetic by-product, important for guidance systems of intercontinental missiles, is more precise information on the earth's gravitational field.

✦

High Speed Saw Makes Accurate 25 ft. Cuts on Plate Stock for Chicago Warehouse



New 122-CX saw now in operation at Chicago Steel Service Company features 2 saws set at 90° angles. Cross cut has 10′ travel, ripping saw has 25′ travel . . . both cut to desirable tolerances . . . smooth, unbroken edges need little or no finishing. Can be used for wet or dry abrasive cutting. Ty-Sa-Man makes hundreds of types of metal-working saws, cut-off, long cut, mitre, friction, abrasive or combination. Send us your metal-cutting problems.

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SINCE 1885

FREE CATALOG! Write For No. 1249

TY-SA-MAN Machine Co.

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Industry Notes

Staying With It?

National Specialists on Guidance of Aerospace Vehicles got straightened out on a few points of astronautical navigation at a meeting in Boston May 25.

The Army News Service quotes engineer Samuel Leshnover's paper:

"Prediction of Anisoelastic and Vibropendulous Effects on Inertial Navigation System Performance in Linear Random Vibration Environments."

Says ANS:

"What Engineer Leshnover means is that you have to be mighty careful when shopping around for inertial navigation equipment!"

GROUND EFFECT VTOL scale model has been wind-tunnel tested at Princeton University. Vertol design discharges air through periphery of wing.

Contracts

Bendix Aviation — $21-million to continue development and evaluation of the Eagle missile system for the Navy.

Raytheon Co.—$12,500,000 to the Missile Systems Div. for ground support equipment used with Army's Hawk.

Thiokol Chemical Corp.—$10,500,000 to the Longhorn Div. to produce rocket motors for the Army. Motors are built here for

THE S. S. White Industrial Airbrasive® Unit

Not that we advise doing this to your fine crystal glassware, but it seemed to us a dramatic way to show you the versatility and the cool, shockless cutting and frosting action of our Industrial Airbrasive Unit.

Cuts as fine as .008" or large frosted areas are equally easy to make with this amazing industrial tool. A gas-propelled stream of abrasive particles quickly slices or abrades, as needed, almost any hard, brittle material, such as fragile crystals, glass, oxides, metal, minerals, ceramics.

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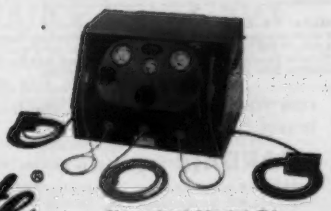
Send us your most difficult samples and we will test them for you.

SEND FOR BULLETIN 5705A ...complete information



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AIR He N₂

COMPRESSION to
12,000 psi
...discharge capacities
to 150 scfm
with
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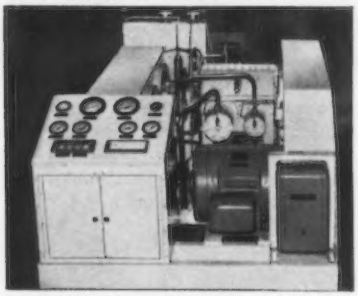
CENTRAL COMPRESSION SYSTEMS

New Technical Data and Catalog. See offer below.

Cardair Central Compression Systems (completely packaged, semi-portable)—are today handling air and a variety of gases—helium, nitrogen, argon, etc.—at pressures ranging from 4,000 to 12,000 psi with discharge capacities from 50 to 150 scfm. Even hydrogen is being safely compressed to elevated pressures.

Systems can be provided from stock with *guaranteed* purification of delivered gas to —100°F. dew point and less than 4 ppm oil content. Specially engineered systems to meet your particular requirements can be supplied from standard components.

This performance is *demonstrated* by exacting rocket and missile service and continuously growing use by prime contractors, suppliers of missile components and controls, and testing laboratories. It is *backed* by over 20 years of compressor design and application experience.



Model PB-CCS—*One of a wide selection of systems* 4-stage air-cooled Compression System—Pressure Range: 6,000—12,000 psig—Induction: 65 to 135 psig—Capacity: 75 scfm N_2 and Air; 70 scfm He—Guaranteed Gas Purity: —100°F. Dew Point, less than 4 ppm oil content.

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Dept. 10, 307 N. Michigan Ave., Chicago 1, Ill.
WESTERN STATES DISTRIBUTOR:
General Air Equipment
824 Hollywood Way, Burbank, Cal.

Circle 30 on Inquiry Card

Industry Notes

Falcon, Nike-Hercules, and La-Crosse.

Temco Aircraft — $1,870,000 from Navy for Terrier booster and sustainer motors.

Sperry Gyroscope Co. — $19,-685,291 from the Navy for Polaris submarine navigation systems and field engineering.

The Hallicrafters Co. — $12-million from the Air Force to produce electronic countermeasure equipment designed to disrupt hostile radar and missile guidance systems. Equipment will be used on SAC's B-52 bombers.

Avco Corp.-Lycoming Div. — $14,234,460 for T53 gas turbines.

North American Aviation-Autonetics Div. — $7,400,000 follow-on subcontract from Republic Aviation for multi-purpose Nasarr R14A search and range radar to be used in F105-D.

The Gyrodyne Co. of America —$5.5-million from the Navy to produce DSN-3 drone helicopters to be used in antisubmarine warfare.

Giannini Controls Corp. — $700,000 from Bendix Aviation Corp. for free gyros to guide Talos.

New Facilities

B. F. Goodrich will expand its rocket motor plant in Rialto, Calif., to three times present manufacturing capacity.

Hughes Aircraft Company's ground systems group has begun operations in its advanced radar test center in Carbon Canyon, Calif.

Radiation Inc. has dedicated

Save Time—Save Labor—Save Material

with Steel City Ductility Testers

Test incoming material for drawing qualities to be sure it will do the job for which you bought it and you'll avoid scrap and eliminate costly wasted effort. How? With a Steel City Ductility Testing Machine. Two concentric pistons do the job. Outer piston grips test piece against head; inner piston makes the cup. Gripping and load application are automatic. Piston speed is easily adjustable.

Distributors in most major metalworking areas

Steel City Testing Machines Inc
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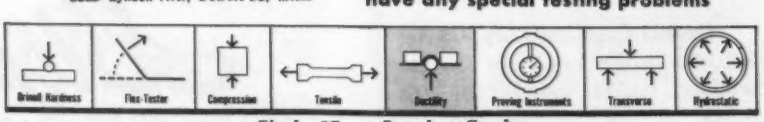
Available in two compact floor models for thicknesses up to ⅛" and ¼", and a bench model for thin metals 0.001" to 0.062". Hydraulic capacities up to 40,000 lb. Specimens up to 4" wide tested with ease. Depth indicator incorporates friction brake to hold readings. Easy-to-read load gage has maximum-indicating hand. Write for detailed specifications.

Write or call Steel City if you have any special testing problems



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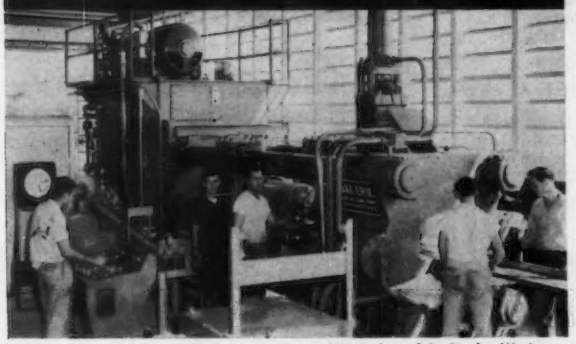

Miami plant of the Stanley Works

Metal fabricating, machining, plastic control manufacturers, heat treating plants – they're all here to serve the electronics and aircraft and missile manufacturers of America.
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Send for 30 section Economic Survey of Metropolitan Miami

This important survey will be mailed to you free of charge – in strictest confidence – if you write, on your letterhead, to the address listed below.

Write: C. Richard Welsh, Director

DADE COUNTY DEVELOPMENT DEPARTMENT

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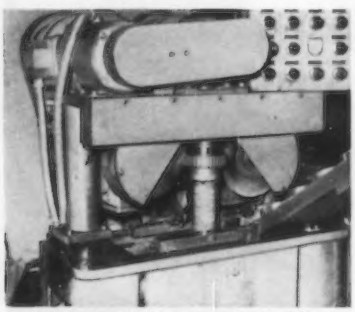
BEFORE BRUSHING—Clutch component . . . with sharp edges plus fine machining chips and burrs still carried inside teeth.

AFTER BRUSHING—Edges and surface junctures are uniformly precision blended. Chips and burrs are thoroughly removed to help assure trouble-free operation of the installed part.

Precision finish . . . in 7 seconds flat

. . . capacity 360 parts-per-hour with OSBORN Power Brushing



TWIN POWER BRUSHES deburr and edge-blend these parts on 7-second cycles. Osborn 6" Monitor® Brushes—operating at 1750 rpm—do the job at high production rates. Quality is excellent . . . cost is low.

IF you precision finish parts, and want to do the job faster . . . with improved quality . . . at less cost—today's Osborn Power Brushing methods can help you do it.

For example—this leading manufacturer uses a dual-brush setup to automatically deburr and edge-blend precision clutch parts. In addition to the *versatility* and *precise quality control* he's afforded by Osborn Power Brushing—he finds finishing operations are done faster and at significantly lower cost.

It's typical of how *you* can pinpoint savings, too. An **O**sborn **B**rushing **A**nalysis—made in your plant at no cost or obligation—is the first step. Write us for full details. *The Osborn Manufacturing Company, Dept. AM-11, Cleveland 14, Ohio.*

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METAL FINISHING MACHINES . . . AND METHODS

MAINTENANCE, PAINT AND POWER BRUSHES • FOUNDRY PRODUCTION MACHINERY

Industry Notes

new national headquarters and electronics facilities at Palm Bay, Fla. This is the first phase of a proposed multi-million dollar building program.

Union Carbide is installing $4,871,000 facilities for ceramics and metal fundamental and applied research at the Oak Ridge, Tenn., plant which it operates for the AEC.

Fairchild Camera & Instrument Corp. is installing the country's largest ultra low pressure space chamber, an 18 x 18 x 17-ft., 45-ton facility, at its Syosset, L. I., plant. Firm will build a $1,400,000 Environmental Test Laboratory for testing complete intelligence gathering and other systems under space environments.

Norton Company, Worcester, Mass., maker of abrasive products, has unveiled a $6½-million plant. New facility, to be known as Plant 8, provides added capacity for manufacturing resinoid, rubber, and shellac-bonded grinding wheels.

American Laboratories Div., American Electronics, is now operating a sand drop shock tower for testing ICBM hard site equipment. It can handle loads up to 1200 lb.

Thiokol Chemical Corp. recently unveiled 12 new operating and engineering buildings at its Redstone Div., Huntsville, Ala. They will be used in firm's solid propellant research and manufacture.

Business Moves

Boeing-Wichita Div. announces a new computer center specializing in numerical control service for all industries.

General Electric Co., Silicone Products Dept., is undertaking a 24-month program for increased production. New construction begins with manufacturing facility to be completed by October.

Hughes Aircraft formed a new components division to develop and

Industry Notes

market commercial microwave components. Firm's ground systems group expects to hire 600 engineers and scientists during the next nine months.

University of California is offering a filmed series of 21 lectures on "Ballistic and Space Vehicle Systems." The rental films were produced in cooperation with Space Technology Labs.

Douglas Aircraft Co. announces assignment of Army free - flight weapon systems responsibilities to its Charlotte, N. C., Div. Responsibilities will include direction of pre-proposal, proposal, research, development and production for Army rocket programs.

Bell Aerospace Corp. will be formed as wholly-owned subsidiary of Textron Inc. Later will buy Niagara Frontier, Bell Helicopter, and Hydraulic Research and Manufacturing defense and aircraft Divs., plants of Bell Aircraft, for about $30-million. Bell's top management would be retained.

Bendix Aviation Corp. was appointed sole distributor and service representative in the U.S. for machine tool numerical control systems manufactured by Ferranti, Ltd.

Mt. Ten Bosch has formed a separate division specializing in quantity production balancing of all types of rotors.

Ling - Altec Electronics, and Temco Aircraft Corp., plan merger into Ling-Temco Electronics, Inc.

Production Techniques

New welding tip at General Electric's Ordnance Dept. applies flat instead or round welding wire. Tip is expandable, saves an estimated $40,000 a year.

Samarium-153, dissolved in hydrochloric acid, can measure tiny variations in blade thickness. Technique was developed at General Motors Research Laboratories.

Polaris motor testing is done with high energy gamma rays. Automatic machine, built by Rucker Co., is enclosed in concrete block housing. Rays from Cobalt 60 test solid propellants used in first and second stage motors.

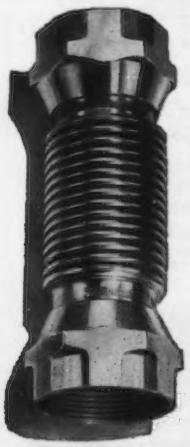
Electrohydraulic servo system is credited with increasing life of wing spar millers at Republic Aviation and McDonnell Aircraft. Developer: Moog Servocontrols.

Mach. 8 speeds will be simulated at Lockheed-Burband, which received two Air Force contracts to study re-entry of 50 models. Lockheed will also study landing problems of glide vehicles such as Dyna-Soar.

Fuel sources for auxiliary power can be solid-fuel types, according to AiResearch Manufacturing Co. Firm used solid propellant grain in 32 minute hot gas run on a 30 KVA

STAINLESS
FlexDucts & Bellows

• which handle high temperature corrosives
• which withstand drastic pressure changes, vibration & sinuous alignment



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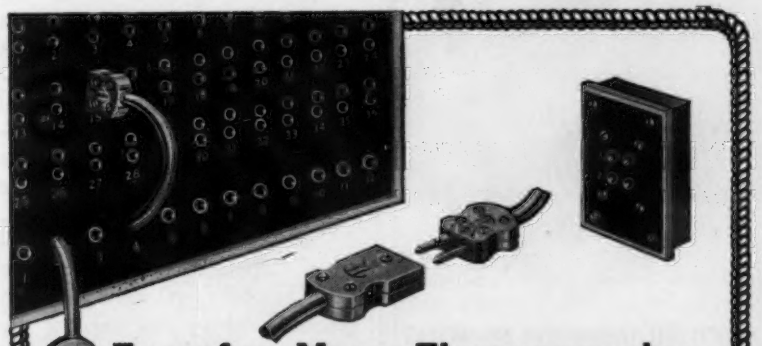

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Connector Panels T-E has one for your exact needs. These panels provide flexible, centralized control in transferring any number of thermocouples to indicating, multi-point recording and controlling pyrometers. Ideal for patch panel use, they are available in many compact shapes and sizes — with interchangeable plugs and jacks in I-C, C-C, and C-A. A panel for 48 thermocouples and 16 pyrometers measures only 13¼" x 7⅞". Polarity markings and screw-fastened connections make wiring easy.

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Write for Bulletin 23—1

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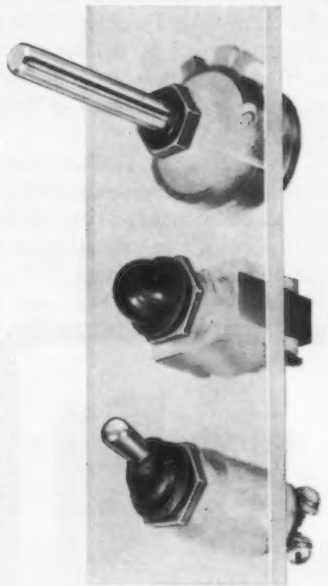

- Fit all industrial electrical controls.
- Meet Military Specifications: MIL-B-005423A (ASG), MIL-B-19257 (Ships), SCL-6303 (Sig. Corps), Par. 183.10-20, Part (B) U.S. Coast Guard.

SEND FOR CATALOG 359A-9 *describing items above, also seals for circuit breakers, indicator lights and other electronic components.*

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Circle 38 on Inquiry Card

Industry Notes

turbo alternator, found no degradation of turbine performance from hot gas contamination.

Package to be impacted on moon within two years will be fabricated by Aeronutronic. Weighing 300 lb., it will be launched from craft being constructed at NASA's Jet Propulsion Lab.

Thin "T-1" alloy steel is used in Army's new Sergeant system. Semi-trailer launcher weighs only 16,000 lb., some 7000 lb. less than if standard steel was used.

MASTER CATALOGUE of every part required to build rocket engine is produced by IBM computer at Rocketdyne. Note H-1 in background.

Expanding Computer Market

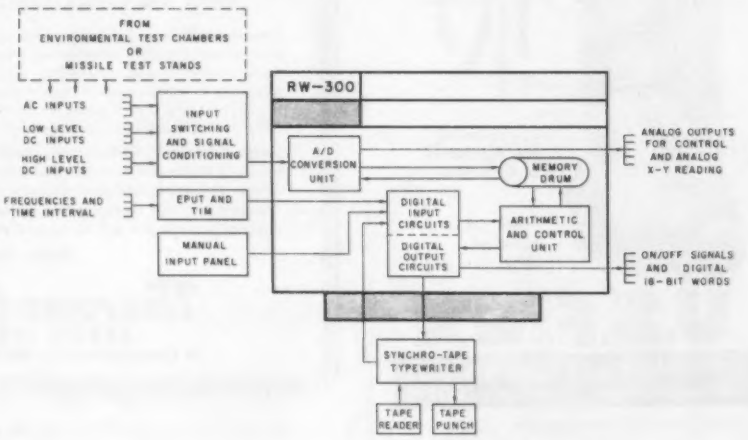
Two practical test applications of the RW-300 computer illustrate growing uses for scientific computers in the aircraft/missile industry.

One system, to be installed at Douglas Aircraft's Santa Monica plant controls testing of complex servo systems for an advanced missile, in an automatic closed loop. The second, at the Sperry Utah Engineering Laboratory, in Salt Lake City, is used primarily for on-site control and data reduction.

In the Douglas system, the computer automatically calibrates the servo amplifier and networks, and generates driving functions for the servo under test. Then measures the resulting systems response, performs the necessary calculations, plots the resulting data, and monitors vibration, pressure, and temperature limits during test.

Douglas predicts that use of the computer will reduce testing time from a minimum of 90 minutes for present manual methods, to less than three minutes. This will allow complete full scale testing of short-life, high tolerance, production servos. Test procedures may be more elaborate, consequently more parameters and limits may be scanned and checked. Component reliability should improve accordingly.

In the Salt Lake City application, computer installation will be used initially for testing components



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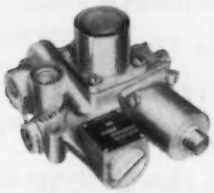
are our main products

First, imaginative design; then experienced thoroughness through development, tooling, production, assembly and tests, all under strict quality control in an unusually well equipped plant . . . we can help you solve your special problems . . .



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Industry Notes

and subsystems for the Sergeant Missile. The prime function of this data acquisition system is to acquire data from any number of tests and render it into readable print-out form.

The computer can be connected to up to 320 signals in the form of frequencies, and a-c, and d-c voltages at several levels.

Constant limit checks can be made to prevent excessive loading of the component under test, making tests "fail-safe." If the limit on any parameter under test is reached, an audible alarm sounds.

Savings in time by using the on-line computer are shown in the ratio of one computer hour to 250 man-hours. High as it may be, this ratio does not convey the significant increase in efficiency. In terms of money saved, the system is expected to pay for itself (including installation and training costs) in between six months to a year.

Aerospace Log

April 15—Discoverer XI orbited by Thor-Agena A. Malfunction prevents return, recovery.

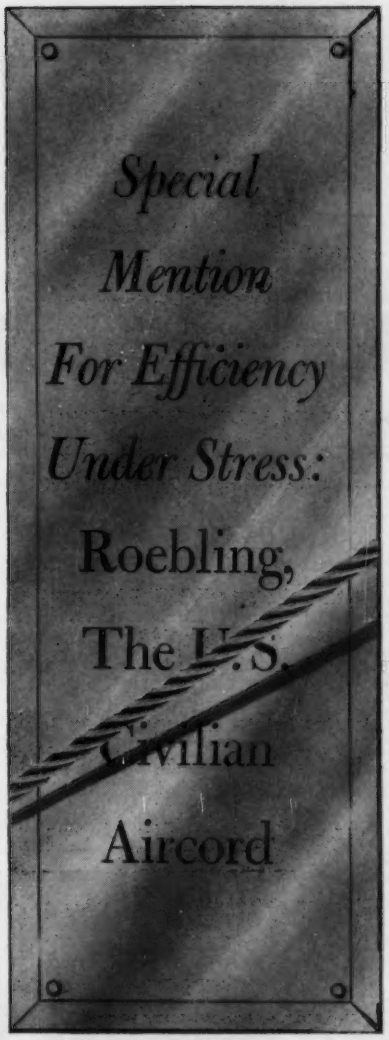
April 20—Pershing launched on successful 30 mile test flight. Dummy second stage.

April 21 — Titan advanced model goes 5000 miles over Atlantic Missile Range. Complete two-stage operation.

April 26—Object of about nine inches diam. discovered in orbit. Believed a fragment of Transit 1-B.

April 28—Army fires test model of Nike Zeus at White Sands. First test of new underground launching cell.

April 28—Portions of B-58 test plane, missing since April 22, found in Great Salt Lake.



Roebling Aircord—tinned or galvanized carbon steel—comes to you bearing an unparalleled "research pedigree." It is built and tested to exceed *military* specifications: constructional stretch has been virtually eliminated. Roebling makes Lock-Clad Aircord (aircraft cable with aluminum tubing swaged around it), stainless steel aircord, assemblies with fittings swaged to cable ends, as well as a complete line of slings.

Plane manufacturers and air supply houses interested in the qualities of Roebling aircord assemblies or slings, may address inquiries to Wire Rope, John A. Roebling's Sons Division, Trenton 2, N. J.

ROEBLING

Branch Offices in Principal Cities
John A. Roebling's Sons Division
The Colorado Fuel and Iron Corporation

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HOLEX Type 2100 Pressure Cartridges have dual bridge-wire circuits, Bendix-type receptacles, and convenient thread-in bodies.

Be weeks ahead . . . cut research and development time! HOLEX Type 2100 Pressure Cartridges are available with energy output ratings from 10 to 135 foot pounds for actuation of devices on aircraft, missiles or rockets —cablecutters, thrusters, parachute ejectors and other mechanisms requiring a high-pressure energy source for a short time period.

TO HELP YOU SELECT . . . HOLEX *Technical Data Sheet 2100 provides a simplified formula to help you select the correct HOLEX Pressure Cartridge for your application. THERE'S A COPY FOR YOUR FILE. Write Dept. G.*

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1601-A

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A More Efficient Method for Forming Space Age* Metals to 1800 Degrees F. and above

***titanium *beryllium *molybdenum *mag-thorium *precipitation hardened stainless steels**

Materials, impossible to form at room temperatures, become workable at elevated temperatures since ductility is generally increased and yield strength decreased. Hot sizing eliminates furnace forming, reduces or eliminates springback and stress relieves parts.

Clearing retractable bed hot platen presses are available with forming tonnages of 75, 150 and 300 tons exerted vertically and horizontally. Platen surface areas—9 square feet to 20 square feet. Building block design allows several presses to be "ganged" and operated individually, or in any combination of units.

Presses, like the above, are also well suited to low temperature plastic laminating.

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